



Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Trauma Prevalence and Resource Utilization During 4 COVID-19 “Surges”: A National Analysis of Trauma Patients From 92 Trauma Centers

Adel Elkbuli, MD, MPH,^{a,*} Brendon Sen-Crowe, MS,^a
 Jennifer L. Morse, MS,^c Ransom J. Wyse, MPH,^c
 Gina M. Berg, PhD, MBA, MSMFT,^{d,e} Jeneva M. Garland, PharmD, MEd,^c
 Andrea Slivinski, DNP, RN,^f James R. Dunne, MD,^{g,h}
 Samir M. Fakhry, MD, FACS,^c and Mark McKenney, MD, MBA, FACS^{a,b}

^a Division of Trauma and Surgical Critical Care, Department of Surgery, Kendall Regional Medical Center, Miami, Florida

^b University of South Florida, Tampa, Florida

^c Center for Trauma and Acute Care Surgery Research, HCA Healthcare, Nashville, Tennessee

^d Wesley Medical Center, Wichita, Kansas

^e Department of Family and Community Medicine, University of Kansas School of Medicine-Wichita, Wichita, Kansas

^f Mission Hospital, Asheville, North Carolina

^g Department of Surgery, Memorial Health University Medical Center, Savannah, Georgia

^h Mercer University School of Medicine, Savannah, Georgia

ARTICLE INFO

Article history:

Received 19 November 2021

Received in revised form

14 February 2022

Accepted 14 February 2022

Available online 14 March 2022

Keywords:

COVID-19 pandemic

Injury distribution

Resource utilizations

Trauma systems

Traumatic injuries

ABSTRACT

Introduction: We aim to assess the trends in trauma patient volume, injury characteristics, and facility resource utilization that occurred during four surges in COVID-19 cases.

Methods: A retrospective cohort study of 92 American College of Surgeons (ACS)-verified trauma centers (TCs) in a national hospital system during 4 COVID-19 case surges was performed. Patients who were directly transported to the TC and were an activation or consultation from the emergency department (ED) were included. Trends in injury characteristics, patient demographics & outcomes, and hospital resource utilization were assessed during four COVID-19 case surges and compared to the same dates in 2019.

Results: The majority of TCs were within a metropolitan or micropolitan division. During the pandemic, trauma admissions decreased overall, but displayed variable trends during Surges 1-4 and across U.S. regions and TC levels. Patients requiring surgery or blood transfusion increased significantly during Surges 1-3, whereas the proportion of patients requiring plasma and/or platelets increased significantly during Surges 1-2. Patients admitted to the hospital had significantly higher Injury Severity Score (ISS) and mortality as compared to pre-pandemic during Surge 1 and 2. Patients with Medicaid or uninsured increased significantly during the pandemic. Hospital length of stay (LOS) decreased significantly during the pandemic and more trauma patients were discharged home.

Conclusions: Trauma admissions decreased during Surge 1, but increased during Surge 2, 3 and 4. Penetrating injuries and firearm-related injuries increased significantly during the

* Corresponding author. Department of Surgery, Kendall Regional Medical Center, 11750 40th Street, Miami, FL 33175. fax: +305 480 6625.

E-mail address: adel.elkbuli@hcahealthcare.com (A. Elkbuli).

0022-4804/\$ – see front matter © 2022 Elsevier Inc. All rights reserved.

<https://doi.org/10.1016/j.jss.2022.02.053>

pandemic, patients requiring surgery or packed red blood cells (PRBCs) transfusion increased significantly during Surges 1-3. The number of patients discharged home increased during the pandemic and was accompanied by a decreased hospital length of stay (LOS).

© 2022 Elsevier Inc. All rights reserved.

Background

On March 11, 2020, COVID-19 was declared a global pandemic by the World Health Organization (WHO), and the United States (US) began issuing shelter-in-place and/or stay-at-home-orders (SAHOs).^{1,2} As a result, the unemployment rose and increasingly higher rates of uninsured patients began presenting to trauma centers (TCs) during the pandemic.³ The emergency department (ED) visits dwindled during the first surge and elective surgeries were canceled, inflicting substantial financial strain on the healthcare system.^{4,5} Individuals spent progressively more time indoors, reducing motor vehicle collisions (MVCs), and cases of interpersonal violence became increasingly more common.⁶⁻⁸ Despite the enforcement of social distancing measures and the development of vaccines, COVID-related deaths continue to escalate especially among minorities and elderly populations.⁹⁻¹²

Much of the preliminary studies published in peer-reviewed journals have focused on the pandemic's initial timeframe or the relative "SAHO initiation-to-publication period," which reflects aspects of the early pandemic scenario. This is true of hospital-based outcomes research, including studies focusing on select patient types, e.g., trauma and acute care surgery patients and elective versus non-elective surgeries.¹³⁻¹⁶ Few studies have utilized large datasets to assess the generalizability of COVID-19 trends. The studies that attempted to assess the effect of COVID-19 surges on traumatic injuries and trauma system operations only utilized regional TC data or only analyzed one surge period.^{15,17,18}

Trends in trauma-related volume and resource utilization that occurred during four distinct time periods, which generally characterize national "surges" in COVID-19, case volume were assessed. We hypothesize that trauma admissions, trauma-related surgeries, hospital resource utilization, and healthcare charges will decrease during surges 1 and 2, and resume to baseline upon lifting SAHOs. In addition, we hypothesize that firearm-related injuries will increase throughout all surges and remain proportionally high. To our knowledge, this is the first study to compare changes in the prevalence and resource utilization within trauma populations & operations during four COVID-19 pandemic surges, and across various trauma center levels and multiple U.S. regions.

Methods and Materials

This was a retrospective cohort study of 92 American College of Surgeons (ACS)-verified TCs from a national hospital system located in all four US Census regions (West, Midwest, South, Northeast). Individual TC characteristics were

collected, including the location, bed count, and market area population density, as defined by the US Department of Agriculture (USDA). The study compared the pre-pandemic period (March 1, 2019-January 31, 2020) to the pandemic period (March 1, 2020-January 31, 2021), assessing the impact on demographics, injury distribution, hospital resources, and cost utilization.

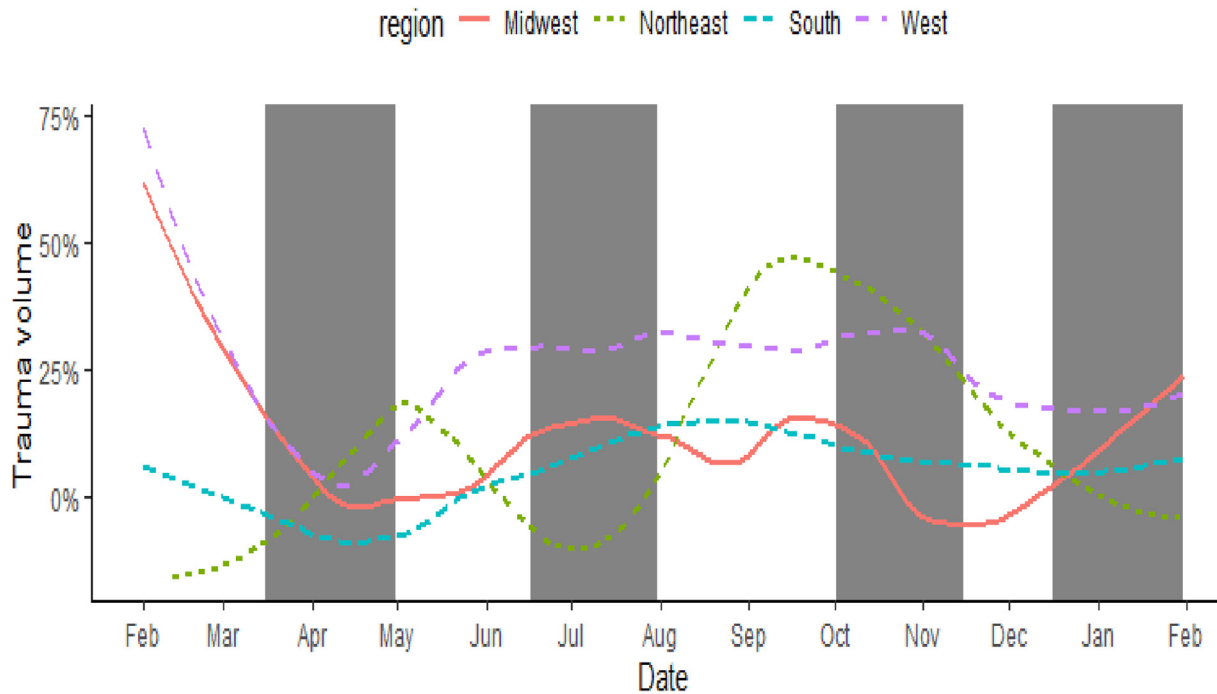
A focused analysis of four surge periods was performed. Surge periods were defined as 3-wk time periods before and after national trends (rounded to the nearest half-month). These periods were based on a graphical representation of new COVID-19 cases nationwide, as extrapolated from previous studies.^{14,15} Timeframes for surges were Surge 1 from March 16, 2020-April 30, 2020, Surge 2 June 16, 2020-July 31, 2020, Surge 3 October 1, 2020-November 15, 2020, and Surge 4 from December 16, 2020-January 31, 2021.

Patient-level data were collected from the central trauma registry and system-wide electronic data warehouse of our institutional healthcare national hospital system, which is comprised of information on arrival dates, demographics, injury characteristics, outcomes, and total charges. Patients were excluded, if they were not a trauma activation or consultation from the ED, or not yet discharged. Transfer patients were also excluded in order to eliminate the introduction of bias that may arise from differing transfer practices between states and regions and/or variations in the care received at the initial facility and to primarily focus on the performance of the TCs being assessed.

All trauma data conformed to the National Trauma Data Standard International (NTDS). Patient demographics and clinical characteristics included age, sex, race/ethnicity (White, Asian, Black, Hispanic, Other), insurance status/type (Medicaid, Medicare, Private, Uninsured, Other), injury type (blunt, penetrating), Glasgow Coma Scale (GCS), and Injury Severity Score (ISS). International Statistical Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) external cause-of-injury codes were grouped based on the Centers for Disease Control and Prevention (CDC) recommendations. In addition, metrics of resource utilization were collected and analyzed, including the number of trauma-related ED visits, trauma volume, and the number of patients who required intensive care unit (ICU) care or mechanical ventilators. Trauma volume was defined as the number of trauma admissions. ICD-10 procedure codes were used to identify patients who had surgery. Patient financial data was used to calculate the total charge for each patient including all ancillary and room charges.

The total number of patients presenting to the TCs for a trauma-related event was plotted using a locally weighted scatter plot smoother (LOESS) curve, with an emphasis on the four surge periods. Additional information regarding the year-

A By Region (Baseline: 2019)



B By Level (Baseline: 2019)

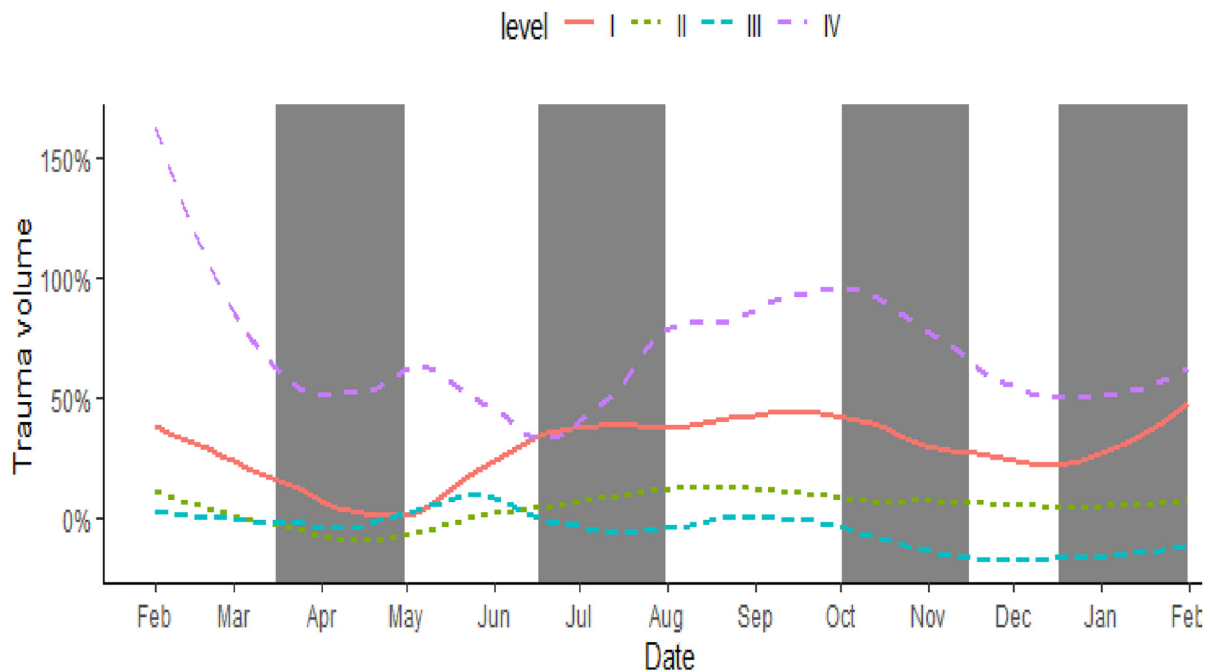


Fig. 1 – (A) Trauma Volume (Admissions) Stratified by U.S. Region. Trauma volume is relative to the volume in 2019 (baseline volume). A trauma volume of 0% represents the baseline trauma volume in 2019, whereas 100% refers to a relative doubling (100% increase) in trauma volume. Shaded columns outline each surge period analyzed. (B) Trauma Volume (Admissions) Stratified by Trauma Center Level. Trauma volume is relative to the volume in 2019 (baseline volume). A trauma volume of 0% represents the baseline trauma volume in 2019, whereas 100% refers to a relative doubling (100% increase) in trauma volume. Shaded columns outline each surge period analyzed.

to-year percentage change was plotted overall and by demographic and injury groupings.

For each surge period, descriptive statistical analysis was used to analyze changes between the pandemic and pre-pandemic periods. The distribution normality of continuous data was determined by plotting values on a histogram. Any data that were not normally distributed are summarized as median and interquartile ranges. Demographics, injury characteristics, outcomes, and resource utilization were compared between periods using univariate analyses, including Pearson χ^2 for categorical variables and Wilcoxon rank-sum for continuous variables. Presented data demonstrate both proportional categorical shifts, as well as year-over-year percentage changes. Multivariable logistic regression was used to estimate the association of the pandemic period on chosen outcomes. Adjustments included age, number of NTDS-defined comorbidities, and ISS category. The effect of the pandemic period was presented separately for each surge and summarized using an adjusted odds ratio comparing the pandemic period to the pre-pandemic period. The R software version 3.6.2 was used for statistical analyses and P -values < 0.05 were considered significant. This research was determined to be exempt from Institutional Review Board (IRB) oversight in accordance with current regulations and institutional policy.

Results

Sample selection

Ninety-two TCs from a nationwide hospital system were included in this analysis, (Supplementary Table 1: Supplementary Files), consisting of eight (8.7%) Level 1 (L1) TCs, 38 (41.3%) Level 2 TCs, 27 (29.3%) Level 3 TCs and 19 Level 4 (L4) TCs. The majority of TCs were from the Southern region (66/92, 71.7%), and all hospitals were located in metropolitan or micropolitan areas (Fig. 1A, Supplementary Fig. 1; Supplementary Table 1: Supplementary Files). Hospital bed count ranged from 22 to 879.

Pandemic “Surge” trends

Data from the pandemic period were compared to the same period in the previous year, revealing an absolute decrease in patients’ admissions overall. However, surge periods 2-4 showed a year-over-year increase in daily trauma activations (Fig. 2). Surge 1 showed a 12% decrease and year-to-year percentage increases in daily trauma activations during Surges 2-4 of 7.3%, 9.4%, and 4.1%, respectively (Fig. 2). This difference varied across regions, and TC levels. The Western region

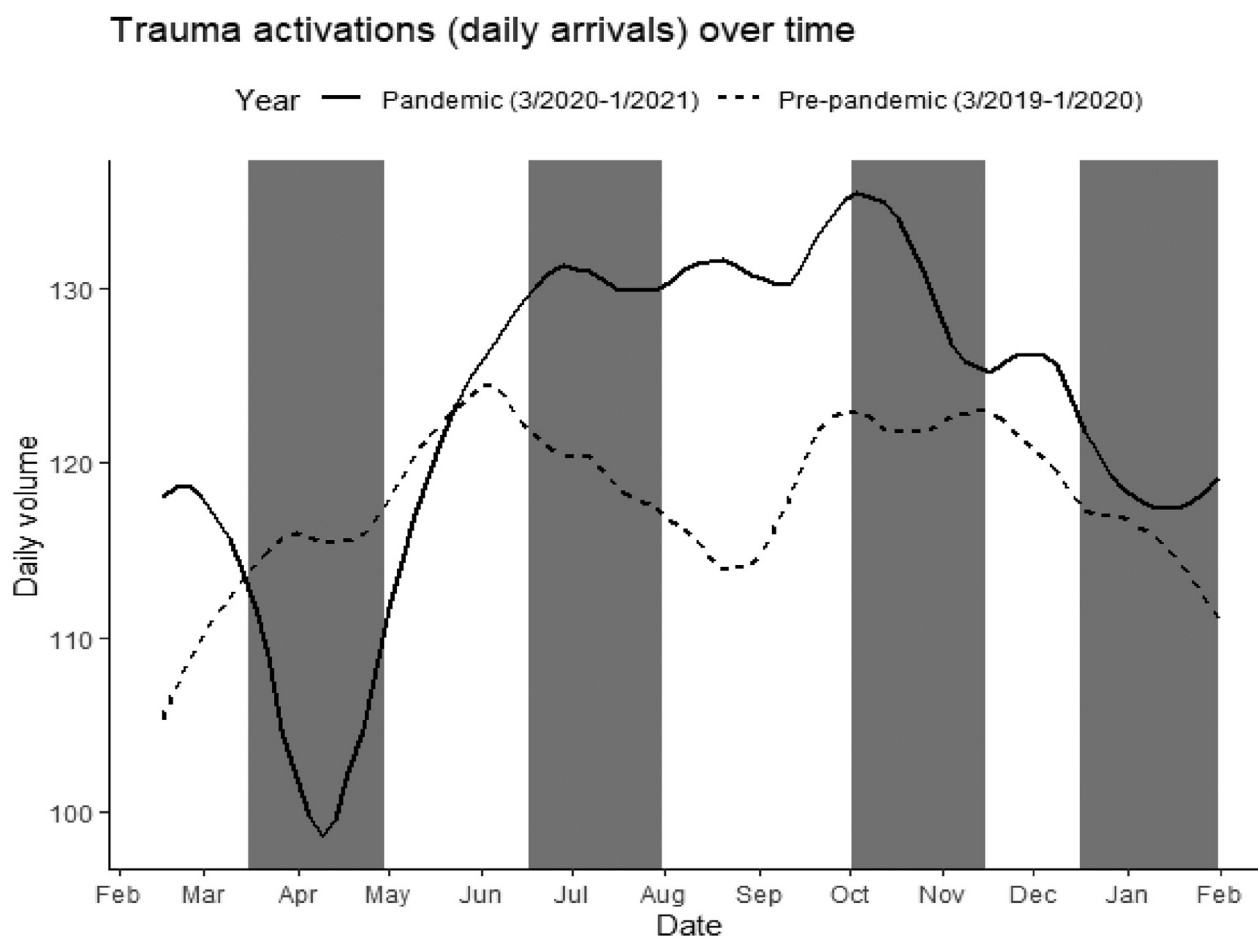


Fig. 2 – Trauma Activations before (2019) and during all four COVID-19 case surges (2020-2021). Shaded columns outline each surge period analyzed.

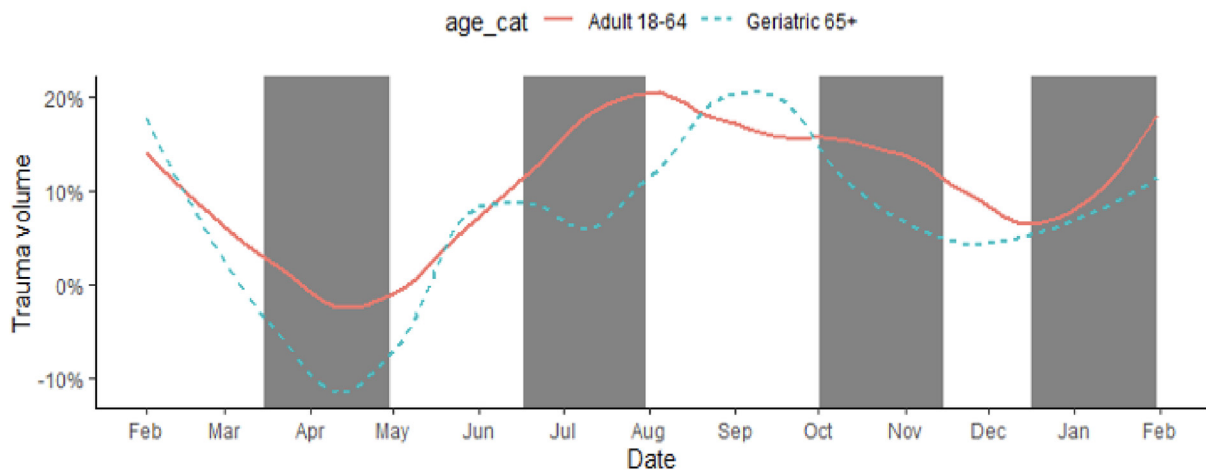
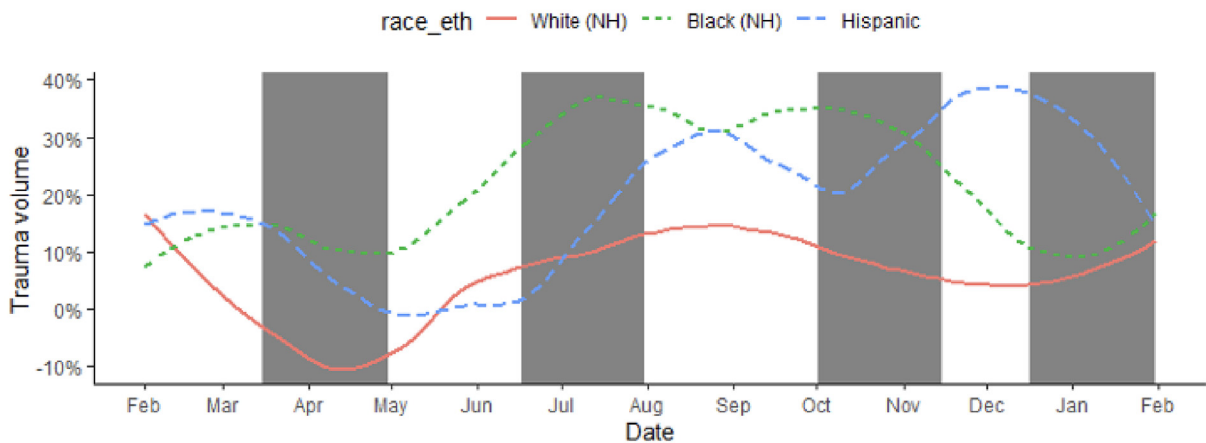
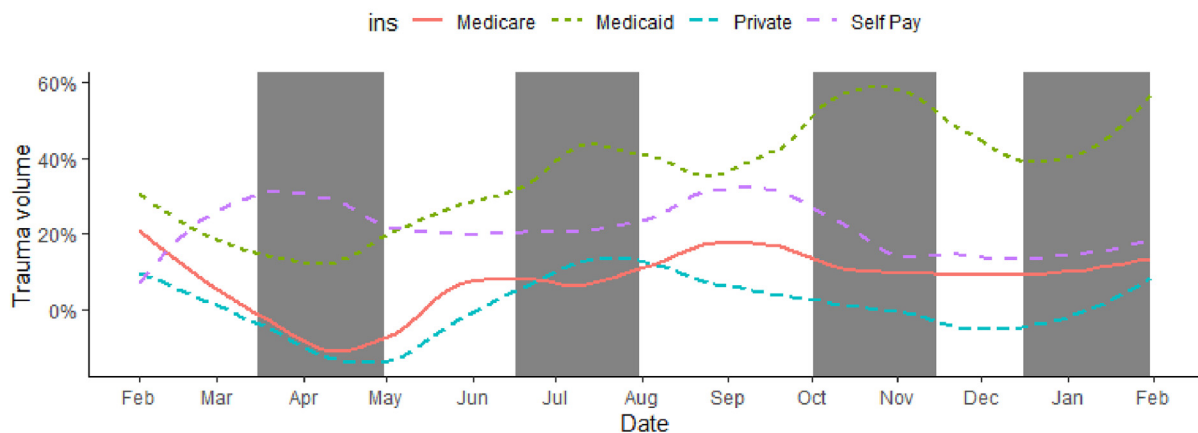
A By Age (Baseline: 2019)**B** By Race (Baseline: 2019)**C** By Ins (Baseline: 2019)

Fig. 3 – (A) Trauma Volume (Admissions) Stratified by Age. During Surge 2, adults aged 18-64 and geriatrics aged 65+ increased significantly. Adults aged 18-64 increased from 2912 in 2019, to 3276 (+12.5%), whereas geriatrics increased from 2101 to 2149 (+2.3%) during the same period. Trauma volume is relative to the volume in 2019 (baseline volume). A trauma volume of 0% represents the baseline trauma volume in 2019, whereas 100% refers to a relative doubling (100% increase) in trauma volume. Shaded columns outline each surge period analyzed. **(B). Trauma Volume (Admissions) Stratified by Race.** Black and White patients decreased significantly (–1.2% and –14.3%, respectively) during Surge 1, whereas a significant

showed a smaller decrease in Surge 1 (−5.7%) and large increases in follow-up surges (Surge 2: +20.3%, Surge 3: +28.3%, Surge 4: +15.5%) compared to all regions analyzed (−12%). Level 4 centers had consistently higher volume in the pandemic year compared to the previous study period overall, with no observed decreases, even in Surge 1. Level 1 centers saw a consistently higher proportion of all patients throughout all surge periods compared to the pre-pandemic period (Fig. 1B).

Patient demographics

Volume trend analysis revealed variations in demographics when comparing the pandemic year to the previous year. TCs saw a larger decrease in geriatric patient admissions ≥ 65 (−15.4%) compared to adult patients aged 18–64 [2449 from 2771 (−9.7%)] in Surge 1 (Fig. 3A, Supplementary Table 2: Supplementary Files). In the pandemic's subsequent surges (2–4), geriatric patient admissions made up a statistically smaller proportion of all patients. In these subsequent surges, the adult age group saw large increases of 12.5% (3276 from 2912, $P = 0.005$) during Surge 2, 13.0% (3165 from 2800, $P = 0.063$) in Surge 3, and 5.3% (2763 from 2623, $P = 0.544$) in Surge 4, while the geriatric trauma patient volume (admissions) rose by a smaller percentage year over year [Surge 2: 2.3% (2149 from 2101, $P = 0.045$), Surge 3: 6.8% (2447 from 2291, $P = 0.289$), Surge 4: 5.5% (2468 from 2340, $P = 0.546$)].

Race comparison showed disparities in volume trends across the surges (Fig. 3B). There was a smaller decrease in volume during Surge 1, with larger increases in subsequent surges in the Black and Hispanic patients. Compared to the previous year, during Surge 1, TCs experienced a 14.3% decrease (3093 from 3610, $P = 0.049$) in White patients, while volumes of Black patients were similar (587 from 594; 1.2% decrease, $P = 0.034$), with Black patients making up a significantly larger proportion of patients (12.8% from 11.4%). Furthermore, in Surges 2 and 3, a large increase in the trauma volume of Black patients was observed (Surge 2: 29.5%, Surge 3: 19.9%).

Payer comparison between the pre-pandemic and pandemic periods showed increases in Medicaid and uninsured patients (Fig. 3C). From March 1, 2020–January 31, 2021, there was an overall 12% decrease in uninsured patients. Although, in Surge 1, the number of uninsured patients rose 12.4%, from 817 to 918. In later surges, the proportion of patients on Medicaid experienced a statistically significant increase (Surge 2: 12.3 from 10.2%, Surge 3: 11.3 from 8.7%), and a year-over-year increase from 29.5% to 41.3%. Further stratification of patients by race and insurance revealed the largest

increases occurred among uninsured Black patients in Surge 1 (233 from 167, $P < 0.001$) and among White Medicaid patients in Surge 2 (535 from 478, $P = 0.262$) (Supplementary Table 3: Supplementary Files).

Injury characteristics

During the pandemic period, patients presented with different types and severity of injuries compared to the pre-pandemic period (Table 1). There was a significant increase in ISS (Surge 1: 10.45 from 9.93) and a corresponding 9% increase in the proportion of patients with severe injuries (ISS > 25) in Surge 1 (414 from 360) of the pandemic year compared to 6.9% in the pre-pandemic period. ISS remained elevated in Surge 2 (457 from 347); however, Surges 3 and 4 did not show statistical differences in ISS (Table 1, Fig. 4A). In addition, during Surge 1, the absolute numbers of blunt injuries decreased 15.8% from 4770 to 4017, and penetrating injuries rose 14% from 372 to 501 (Table 1, Fig. 4B). There were significant increases in the proportion of firearm injuries and cut/pierce injuries in Surges 1, 2 and 3, with firearm injuries increasing 47.1% (256 from 174, $P < 0.001$), 43.4% (317 from 221, $P < 0.001$) and 35.3% (318 from 235, $P = 0.011$), respectively, and cut/pierce injuries increasing 28.7% (233 from 181, $P < 0.001$), 14.6% (236 from 206, $P = 0.482$), and 14.8% (209 from 182, $P = 0.62$) in Surges 1, 2 and 3, respectively. There were smaller, non-significant increases in firearm injuries in Surge 4 (269 from 258, $P = 0.928$). In addition, there was a decrease in the proportion of motor vehicle collisions in Surge 1 (20.6% versus 25.3%, $P < 0.001$) and Surge 3 (23.7% versus 25.2%, $P = 0.06$) (Table 1).

Outcome measures and resource utilization

During Surge 1, there was a statistically significant increase in the unadjusted proportion of patients who did not survive to discharge (3.9% from 3%; $P = 0.018$) (Table 2). These differences in mortality were not significant in the adjusted model when age, ISS, and comorbidities were accounted for. Of those discharged alive, there was a statistically significant decrease in patients who were discharged to a skilled nursing facility (SNF) (12.1% from 16.9%; $P < 0.001$). The decrease in patients discharged to SNFs was present both as a proportion of all discharges and as an absolute decrease. A larger proportion of patients discharged home in all surge periods, ranging from 12% to 13.6%, compared to a range of 8.9% to 10.1% in corresponding pre-pandemic time periods ($P < 0.01$). A minimal but statistically significant decrease was found in the Surge 1 length of stay (LOS) compared to the corresponding pre-

increase (+29.5%) in Black patients was noted during Surge 2. In contrast, Hispanic patients increased significantly (+21.2%) during Surge 4. Trauma volume is relative to the volume in 2019 (baseline volume). A trauma volume of 0% represents the baseline trauma volume in 2019, whereas 100% refers to a relative doubling (100% increase) in trauma volume. Shaded columns outline each surge period analyzed. (C). Trauma Volume (Admissions) Stratified by Insurance Status. During Surge 1, privately insured patients decreased significantly, but uninsured patients increased significantly. Patients on Medicaid insurance increased significantly during Surge 2 and 3, whereas, privately insured patients decreased significantly during Surges 3 and 4. Trauma volume is relative to the volume in 2019 (baseline volume). A trauma volume of 0% represents the baseline trauma volume in 2019, whereas 100% refers to a relative doubling (100% increase) in trauma volume. Shaded columns outline each surge period analyzed.

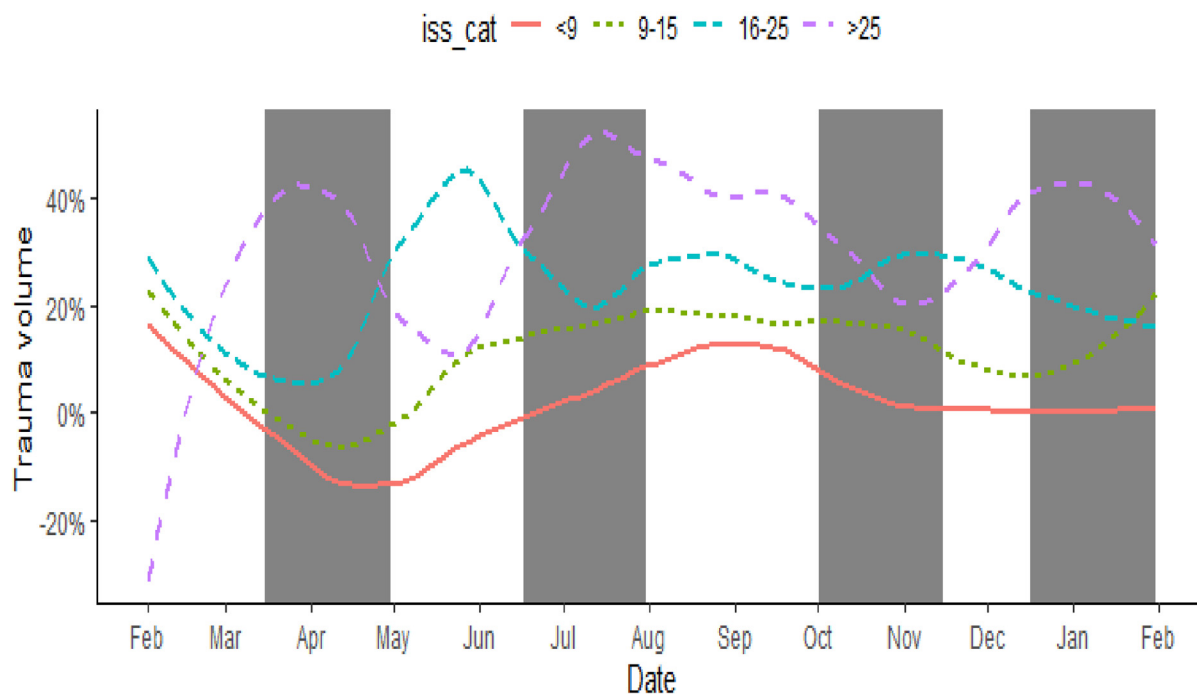
Table 1 – Injury characteristics during all four COVID-19 case surges.

Injury characteristics	Surge 1			Surge 2			Surge 3			Surge 4		
	2019	COVID	% +	2019	COVID	% +	2019	COVID	% +	2019	COVID	% +
GCS	14.08 ± 2.64	14.02 ± 2.75	−0.4	14.06 ± 2.67	14.00 ± 2.80	−0.4	14.05 ± 2.71	14.02 ± 2.76	−0.2	14.14 ± 2.56	14.02 ± 2.71*	−0.8
ISS	9.93 ± 8.17 9 [5-12]	10.45 ± 8.48* 9 [5-13]	11.6	9.80 ± 8.01 9 [5-12]	10.39 ± 8.53* 9 [5-13.25]	6.0	10.10 ± 8.08 9 [5-13]	10.33 ± 8.24 9 [5-13]	2.3	9.87 ± 8.06 9 [5-12]	10.00 ± 7.98 9 [5-12.25]	1.3
ISS Cat <9	2227 (42.7)	1845 (40.2)*	−17.2	2347 (44.1)	2343 (41)*	−0.2	2283 (42.3)	2361 (40)*	3.4	2262 (43.1)	2271 (41.6)	0.4
9-15	2083 (39.9)	1847 (40.2)	−11.3	2050 (38.5)	2271 (39.8)	10.8	2097 (38.8)	2420 (41)*	15.4	2051 (39.1)	2201 (40.3)	7.3
16-25	540 (10.3)	488 (10.6)	−9.6	575 (10.8)	637 (11.2)	10.8	610 (11.3)	672 (11.4)	10.2	559 (10.6)	594 (10.9)	6.3
>25	360 (6.9)	414 (9)*	15.0	347 (6.5)	457 (8)*	31.7	405 (7.5)	448 (7.6)	10.6	373 (7.1)	394 (7.2)	5.6
Inj Type: Blunt	4770 (91.4)	4017 (87.4)*	−15.8	4806 (90.3)	5036 (88.1)*	4.8	4912 (90.9)	5298 (89.7)*	7.9	4710 (89.7)	4942 (90.4)	4.9
Penetrating	372 (7.1)	501 (10.9)*	34.7	442 (8.3)	568 (9.9)*	28.5	431 (8)	545 (9.2)*	26.5	466 (8.9)	456 (8.3)	−2.1
MOI: Same Level Fall	1531 (29.3)	1288 (28)	−15.9	1349 (25.3)	1462 (25.6)	8.4	1438 (26.6)	1608 (27.2)	11.8	1617 (30.8)	1722 (31.7)	6.5
Other Fall	998 (19.1)	957 (20.8)*	−4.1	1097 (20.6)	1118 (19.6)	1.9	1087 (20.1)	1160 (19.7)	6.7	1047 (19.9)	1085 (20)	3.6
MVC	1318 (25.3)	948 (20.6)*	−28.1	1300 (24.4)	1369 (24)	5.3	1363 (25.2)	1400 (23.7)	2.7	1233 (23.5)	1290 (23.8)	4.6
Gun	174 (3.3)	256 (5.6)*	47.1	221 (4.2)	317 (5.6)*	43.4	235 (4.4)	318 (5.4)*	35.3	258 (4.9)	269 (5)	4.3
Cut/Pierce	181 (3.5)	233 (5.1)*	28.7	206 (3.9)	236 (4.1)	14.6	182 (3.4)	209 (3.5)	14.8	195 (3.7)	168 (3.1)	−13.8

GCS = Glasgow Coma Scale; ISS = Injury Severity Score; Inj type = Injury Type; MOI = Mechanism of Injury; MVC = Motor Vehicle Collision.

* Indicates statistical significance ($P < 0.05$).

A By ISS cat (Baseline: 2019)



B By Type (Baseline: 2019)

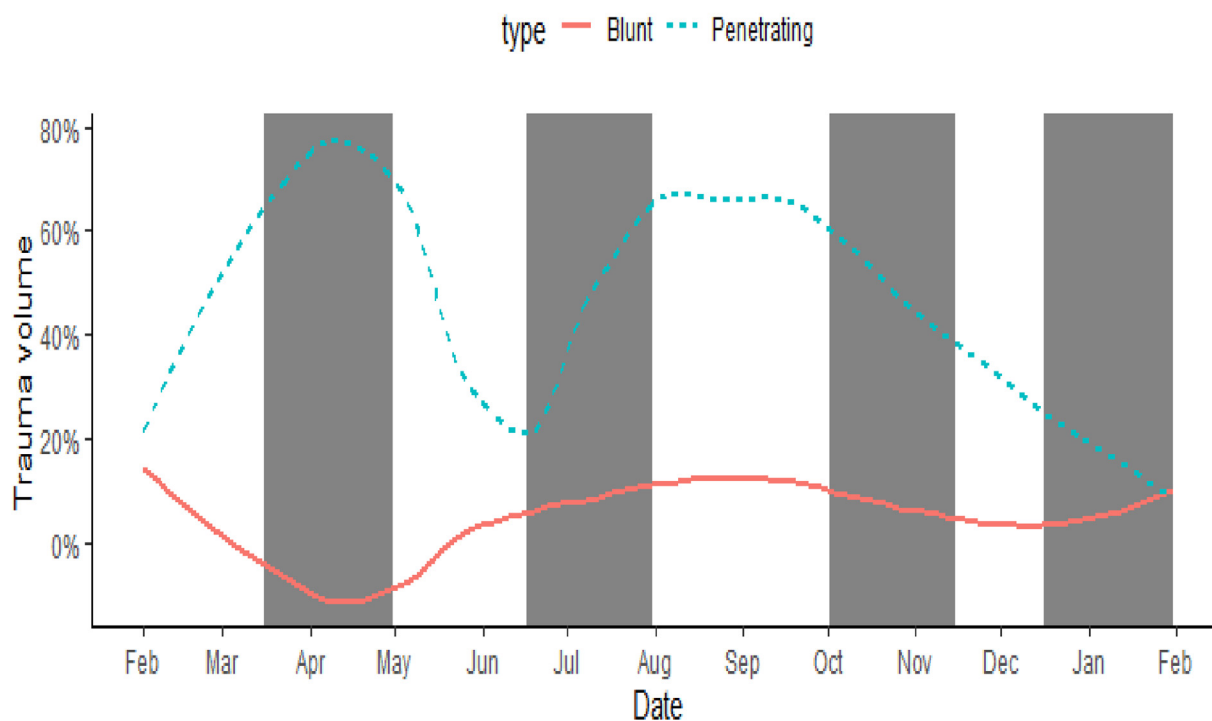


Fig. 4 – (A) Trauma volume (admissions) by ISS category during 4 COVID-19 case surges. (B) Trauma volume (admissions) by injury type during 4 COVID-19 case surges.

Table 2 – Patient outcomes during all four COVID-19 case surges.

	Surge 1			Surge 2			Surge 3			Surge 4		
	2019	COVID	% +	2019	COVID	% +	2019	COVID	% +	2019	COVID	% +
Mortality: Died	158 (3)	179 (3.9)*	13.3	144 (2.7)	193 (3.4)*	34.0	176 (3.3)	172 (2.9)	-2.3	175 (3.3)	186 (3.4)	6.3
Hosp Disp: Home	2658 (50.9)	2325 (50.6)	-12.5	2903 (54.5)	3052 (53.4)	5.1	2790 (51.7)	3047 (51.6)	9.2	2658 (50.6)	2609 (47.7)*	-1.8
Home (Services)	489 (9.4)	549 (12)*	12.3	472 (8.9)	694 (12.1)*	47.0	523 (9.7)	741 (12.5)*	41.7	530 (10.1)	742 (13.6)*	40.0
SNF	884 (16.9)	558 (12.1)*	-36.9	838 (15.7)	618 (10.8)*	-26.3	851 (15.8)	743 (12.6)*	-12.7	890 (17)	815 (14.9)*	-8.4
Rehab	602 (11.5)	564 (12.3)	-6.3	563 (10.6)	690 (12.1)*	22.6	622 (11.5)	695 (11.8)	11.7	574 (10.9)	608 (11.1)	5.9
Hospice	95 (1.8)	105 (2.3)	10.5	78 (1.5)	118 (2.1)*	51.3	114 (2.1)	147 (2.5)	28.9	121 (2.3)	153 (2.8)	26.4
Other Facility	221 (4.2)	165 (3.6)	-25.3	193 (3.6)	201 (3.5)	4.1	202 (3.7)	197 (3.3)	-2.5	182 (3.5)	171 (3.1)	-6.0
LOS (Hosp)	5.57 ± 9.66	5.18 ± 7.55*	-7.0	5.64 ± 9.76	5.45 ± 8.89	-3.4	5.68 ± 8.17	5.73 ± 8.21	0.9	5.53 ± 8.98	5.57 ± 7.12	0.7
LOS (ICU)	1.96 ± 5.19	1.95 ± 4.68	-0.5	1.92 ± 4.81	1.99 ± 5.70	3.6	1.94 ± 4.55	1.96 ± 4.91	1.0	1.83 ± 4.59	1.77 ± 4.35*	-3.3

Hosp disp = Hospital Disposition; SNF = Skilled Nursing Facility; Rehab = Rehabilitation Facility; LOS (Hosp) = Hospital Length of Stay; LOS (ICU) = ICU Length of Stay.

* Indicates statistical significance ($P < 0.05$).

pandemic time frame, with a reduction from 5.57 d to 5.18 d ($P = 0.003$). There was a significant increase in patients who required surgery in surges 1-3 (Surge 1:54.6% from 46.8%, Surge 2:52.5% from 46.9%, Surge 3:51.6% from 49.2%). There was an increase in the proportion of patients who required packed red blood cell (pRBC) transfusion in each of surges 1-3 as follows: Surge 1: increased to 16.9% from 13.7%; Surge 2: increased to 15.9% from 13.4%, Surge 3: increased to 16% from 14.2% (Table 3). There was also an increase in the proportion of patients who required plasma and/or platelets in surges 1 and 2. In addition, the magnitude of the proportion of total charges and average charges per patient were significantly higher during the pandemic period as compared to the pre-pandemic period in Surge 1 (292k from 284k; $P = 0.029$) (Table 3).

Odds ratio

Trauma patients had increased odds of going to the operating room (OR) during Surge 1 and 4 but decreased odds during Surge 2, and 3 (Supplementary Fig. 2A: Supplemental Files). Trauma patients had greater odds of dying in Surges 1, 2, and 4, but not Surge 3 (Supplementary Fig. 2B: Supplemental Files). Reduced odds of ICU admission were observed for all surges (Supplementary Fig. 2C: Supplemental Files). Finally, patients had greater odds of requiring a ventilator during Surges 2-4 (Supplementary Fig. 2D: Supplemental Files).

Discussion

Overall, patient admissions decreased significantly during the first surge but increased in surges 2-4. From March 1-May 31, 2020, SAHOs were largely in place in the majority (73%) of states.¹⁹ Decreased admissions during Surge 1 is consistent with numerous studies.^{8,13-15,20-23} A national survey conducted in June 2020 indicated broad support for SAHOs thus, it might be expected that trauma admissions remained at lower rates.^{24,25} However, there was a non-corresponding increase in trauma volumes for surges 2-4 but not consistent across all participating regions or TC levels. Level 1 TCs were the only TC level to exhibit significant changes during any surge with a significant decrease during Surge 1 but increased significantly during surges 2-4. The subsequent increases at Level 1 TCs in Surges 2-4 may be reflective of increased critical care resources resulting in triage to Level 1 TCs.²⁶

A 12% decrease in admissions was noted system-wide during Surge 1. At the patient level, all age and race groups experienced a decline. Subsequent surges indicated increases in all age groups until Surge 4 when pediatrics declined and may be associated with the winter season.^{26,27} Ghafil et al.¹⁴ analyzed three periods between Jan 1-June 7, 2020 and observed a sharp decline in admissions from February 28-April 9 then a return to baseline. In addition, another study reported a reduction in ED visits from March-April 2020 which is consistent with the results of the current study.⁵

Black trauma patient admissions significantly increased during Surge 2. Public safety statistics indicate there was a dramatic increase in violence in the majority of Black neighborhoods after SAHOs were lifted.²⁸

Table 3 – Resource utilization during 4 COVID-19 case surges.

	Surge 1			Surge 2			Surge 3			Surge 4		
	2019	COVID	% +	2019	COVID	% +	2019	COVID	% +	2019	COVID	% +
Vent (Y/N)	626 (12)	594 (12.9)	-5.1	628 (11.8)	777 (13.6)*	23.7	662 (12.3)	758 (12.8)	14.5	604 (11.5)	690 (12.6)	14.2
Admitted From The ED to Hospital	5210 (99.8)	4581 (99.7)	-12.1	5303 (99.6)	5701 (99.8)	7.5	5386 (99.7)	5884 (99.6)	9.2	5233 (99.7)	5457 (99.9)	4.3
Any Trauma/Emergency Surgery	2440 (46.8)	2507 (54.6)*	2.7	2498 (46.9)	2997 (52.5)*	20.0	2656 (49.2)	3045 (51.6)*	14.6	2535 (48.3)	2710 (49.6)	6.9
Required RBC Transfusion	709 (13.7)	763 (16.9)*	7.6	708 (13.4)	900 (15.9)*	27.1	762 (14.2)	932 (16)*	22.3	801 (15.4)	853 (15.8)	6.5
Required Plasma	231 (4.5)	247 (5.5)*	6.9	252 (4.8)	327 (5.8)*	29.8	266 (5)	317 (5.4)	19.2	247 (4.7)	284 (5.3)	15.0
Required Platelets	234 (4.5)	243 (5.4)*	3.8	227 (4.3)	312 (5.5)*	37.4	266 (5)	295 (5.1)	10.9	273 (5.2)	261 (4.8)	-4.4
Proportion of Total Charges (Pre to Covid)			8.7			12.8			9.5			19.1
Total Charges (Only Surgery Pts)			2.6			10.7			9.6			6.3
Total Charges (Only Pts Who Used ICU)			5.8			12.9			11.7			20.1
Total Charges (Only Activated Pts)			8.4			13.3			7.5			16.0

Vent = Ventilator; RBC = Red Blood Cell; Pts = Patients; ICU=Intensive Care Unit.

* Indicates statistical significance (P < 0.05).

Furthermore, the number of patients who were uninsured or Medicaid increased during the pandemic period. In the initial surge, the proportion of self-pay patients increased. It has been estimated that 6.2 million workers lost health insurance.²⁹ In addition, in Surge 2, all types of payer groups increased. But in subsequent surges (3, 4), all groups except those who were privately insured increased with the largest increase occurring in the Medicaid group. Our results showed Medicaid patients increased and privately insured patients decreased during the pandemic period, whereas Sercy *et al.*³ reported opposite trends in Medicaid and privately insured patients during the pandemic period.³ However, Sercy *et al.*³ only analyzed 6 Level 1 TCs which may limit the generalizability of their results. Moreover, the increase in Medicaid patients is consistent with a report from the Department of Health and Human Services (DHHS) that revealed significantly more patients enrolled in Marketplace or Medicaid coverage.³⁰

ISS increased significantly during Surge 1 and 2. These results are inconsistent with another study by Chiba *et al.*⁹ However, their study was limited to a large academic TC on the West Coast and may not reflect trends at the national level.⁷ Similarly, ISS \geq 25 patients increased significantly during Surge 1 and 2 and is consistent with other studies.^{19,22} Our results help to clarify the discrepancy in trends observed in various studies with respect to the injury severity.^{7,12,14,16,17,19,31-34} In contrast, the multi-state, multi-center design of the current study represents Level 1-4 TCs, with at least 1 TC in each region of the U.S, and affords more generalizable results.

In addition, the causes of injury changed during the pandemic period. Penetrating injuries increased significantly during Surge 1-3 and were accompanied by a significant increase in firearm-related injuries. Our findings are consistent with the findings from multiple studies indicating similar increases in firearm and penetrating injuries.^{6,14,35,36} During Surge 1, background checks, a measurement of firearm sales, were noted to increase by over 1 million when compared to the prior year³⁷ and may influence firearm-related injuries.³⁸⁻⁴⁰ Finally, MVCs were noted to decrease significantly only during Surge 1 and is consistent with multiple studies reporting significant reductions in MVCs during the pandemic.^{12,17,19} The significant increase in mortality during Surge 1 and 2 is consistent with the increases in ISS and penetrating injuries during these time periods. Although our study revealed a significant increase in ISS corresponding with the increase in firearm and penetrating injuries, we understand that ISS may not perform well in cases of penetrating injuries. However, trauma outcomes are likely multifactorial and complex and influenced by several factors beyond ISS including TC level, demographic factors, relative injury burden (singular injury *versus* polytrauma), GCS, TBI status, and injury type and location.⁴¹⁻⁴⁵

The proportional growth in hospital charges was more prominent in Surge 2 and 3 *versus* Surge 1. Similarly, blunt injuries decreased significantly during Surge 1 but increased during Surge 2 and 3. These trends are consistent with the results of Fitch *et al.*⁴⁶ that found patients with blunt injuries had greater hospital charges associated with longer LOS.⁴⁶ On the other hand, the significant increase in the number of trauma and emergency-related surgeries during Surge 1, 2,

and 3 may also affect the cost and is supported by the much greater proportional increases in surgeries during Surge 2 and 3.

However, our results differ from other studies assessing hospital resource utilization. In this current study, patients were less likely to be admitted to an ICU during all surges. The hospital LOS also decreased significantly when SAHOs were in place during Surge 1 and is consistent with the results of other studies.^{7,22} One explanation for this trend is the burden inflicted by critically ill COVID-19 patients who are admitted to an ICU.^{47,48} The elevated case volume of COVID-19 patients in combination with trauma volumes presenting to the hospital may overwhelm the capacity of the facility and result in fewer patients admitted to the ICU.

Similarly, during Surge 1 when the U.S. was most unprepared, ventilators were in short supply and in high demand.⁴⁹ It is possible that the shortage in resources is responsible for our results, as trauma patients exhibited reduced odds of receiving a ventilator during Surge 1 and is consistent with fewer ventilation days during the pandemic period reported in another study.⁷ In contrast, patients were more likely to receive a ventilator during Surge 2-4, and this may reflect the efforts of the nation to increase ventilator distribution.⁵⁰ Moreover, the proportion of trauma patients requiring blood product transfusions increased significantly during Surges 1-3 in conjunction with the rise in penetrating injuries. These findings may highlight patterns of resource usage during times of crisis and mitigate ventilator and blood product shortages that may occur in future surges.^{49,51}

Furthermore, the number of patients discharged home increased significantly during all surges, whereas, significantly fewer patients were discharged to SNFs. This is likely due to decreased availability of facility resources in addition to the closure of facilities and declining revenue during the pandemic period.^{4,52} Although an initial decrease in discharges to a rehab facility decreased during Surge 1, rehab discharges increased significantly during Surge 2 and exhibited smaller, non-significant increases during Surge 3 and 4 as compared to the same dates in 2019. However, data stratified by in-patient rehab discharges was not available. Future studies may consider stratifying TC discharges by in-patient versus outpatient discharge to assess the effect on TC resource utilization.

Hospital charges increased across all surges despite a significant decrease in hospital LOS, but not in the ICU-LOS during Surge 1. This may be surprising as ICU costs have been demonstrated to be among the largest proportional cost category by patients and yet, there were no significant increases in ICU stay in the first three surges.⁵³ Although, cost coverage may be variable over the surges.⁵⁴ Velopulos *et al.*⁵⁵ noted that trauma patients traditionally had a lower burden of self-pay or non-reimbursed patients, COVID related changes in admission rates by payer type suggests that 2020 may not follow that pattern of the financial burden to TCs.⁵⁵

Our study has limitations. First, the definitions of COVID-19 time-periods (e.g., pre-COVID versus COVID; pre-SAHO versus post-SAHO) vary extensively, making the comparison of study results difficult. Second, all TCs were located within metro or micropolitan areas and the majority of TCs resided in the South region. In addition, the sample size of TCs in the Northeast was small ($n = 2$) and limits our ability to draw conclusions in the

Northeast region. Third, patient proportions of insurance status may not be entirely represented in the current study, as there may be a lag of 4 mo for a change in insurance status to be reflected by reports of insurance status.⁵⁶

Building on our findings, we recommend future studies compare the effects on TCs across various geographic distributions, particularly rural and urban areas, to identify trends in injuries and patient demographics that may not be evident in metropolitan areas. In addition, future studies may consider the implementation of TCs from all US regions in order to identify regional differences in trauma patient injuries and outcomes. Furthermore, we recommend that future investigations assess trauma volumes and injury characteristics during periods following the lifting of SAHOs to distinguish trends in trauma volume at the national level and identify points of intervention. In times of collaboration between regions in multicenter TC systems, the establishment of a regionalized trauma network (RTN) has been shown to decrease mortality in the US and is consistent with findings reported in other countries.⁵⁷ The full establishment and implementation of an RTN with a resource allocation system may proactively address and handle changes in the dynamic of traumatic injuries that present in times of crisis (e.g., pandemics, natural disasters, etc.) and economic instability. It is important that measures are taken to increase emergency preparedness that has demonstrated a benefit such as a contact and a case surveillance along that can lead to overall cost-effective protective measures.^{58,59} Finally, we recommend that future studies investigate outcomes and resource utilization among COVID-positive versus COVID-negative trauma patients by employing national datasets, as studies assessing this are limited to statewide studies.^{60,61}

Although this study identified trends throughout the pandemic across all surges on TC admissions, outcomes, and resource utilization, it is uncertain how long the effects of the pandemic will continue to affect trauma systems, trauma operations, and the cost of healthcare. The current study demonstrates some of the detrimental changes in trauma care and may benefit from TC regionalization in order to increase the readiness and preparedness of trauma systems.

Conclusion

Trauma admissions decreased during Surge 1 when SAHOs were in effect and increased in during Surges 2, 3, and 4. Level 1 TCs saw significantly greater proportions of all patients during the pandemic. Penetrating injuries, particularly firearm-related injuries, and the number of patients requiring surgery or packed red blood cells (pRBC) transfusion increased significantly during Surges 1, 2, and 3. Resource utilization increased in association with increasing blunt injuries after Surge 1 when many SAHOs were lifted. Significantly more patients were discharged home, whereas patients discharged to SNFs decreased significantly during all surges. Future studies should further investigate the pandemic effects on traumatic injuries distribution and resource utilization comparing rural to urban TCs in order to identify trends in underserved areas at the national level.

Supplementary Materials

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jss.2022.02.053>.

Author Contributions

All authors made contributions in design, data acquisition, data analysis/interpretation, and drafting/revising the article. The authors have given approval of the version to be published.

Disclosure

None declared.

Funding

None.

REFERENCES

- Timeline. WHO's COVID-19 response. World Health Organization. Available at: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline>. Accessed April 13, 2021.
- Harris R. White house announces new social distancing guidelines around coronavirus. National Public Radio. 2020. Available at: <https://www.npr.org/2020/03/16/816658125/white-house-announces-new-social-distancing-guidelines-around-coronavirus>. Accessed April 13, 2021.
- Sercy E, Duane TM, Lieser M, et al. Effect of the COVID-19 pandemic on health insurance coverage among trauma patients: a study of six level I trauma centers. *Trauma Surg Acute Care Open*. 2021;6:e000640.
- Boserup B, McKenney M, Elkbulli A. The financial strain placed on America's hospitals in the wake of the COVID-19 pandemic [published online ahead of print, 2020 Jul 9]. *Am J Emerg Med*. 2020;45:530–531.
- Boserup B, McKenney M, Elkbulli A. The impact of the COVID-19 pandemic on emergency department visits and patient safety in the United States. *Am J Emerg Med*. 2020;38:1732–1736.
- Sutherland M, McKenney M, Elkbulli A. Vehicle related injury patterns during the COVID-19 pandemic: what has changed? *Am J Emerg Med*. 2020;38:1710–1714.
- Hassan K, Prescher H, Wang F, Chang DW, Reid RR. Evaluating the effects of COVID-19 on plastic surgery emergencies: protocols and analysis from a level I trauma center. *Ann Plast Surg*. 2020;85(Suppl 2):S161–S165.
- Chiba H, Lewis M, Benjamin ER, et al. "Safer at home": the effect of the COVID-19 lockdown on epidemiology, resource utilization, and outcomes at a large urban trauma center. *J Trauma Acute Care Surg*. 2021;90:708–713.
- Sen-Crowe B, McKenney M, Elkbulli A. Social distancing during the COVID-19 pandemic: Staying home save lives. *Am J Emerg Med*. 2020;38:1519–1520.
- Boserup B, McKenney M, Elkbulli A. Disproportionate impact of COVID-19 pandemic on racial and ethnic minorities. *Am Surg*. 2020;86:1615–1622.
- Sen-Crowe B, Lin IC, Alfaro R, McKenney M, Elkbulli A. COVID-19 fatalities by zip codes and socioeconomic indicators across various U.S. regions. *Ann Med Surg (Lond)*. 2021;67:102471.
- Kakulavarapu S, Boneva D, Elkbulli A. SARS-CoV-2 vaccine candidates: a beginning of the end of COVID-19 pandemic-Editorial. *Ann Med Surg (Lond)*. 2021;62:460–462.
- Kamine TH, Rembisz A, Barron RJ, Baldwin C, Kromer M. Decrease in trauma admissions with COVID-19 pandemic. *West J Emerg Med*. 2020;21:819–822.
- Savla P, Wiginton 4th J, Taka TM, et al. Using the decrease in trauma admissions during the COVID-19 pandemic to evaluate compliance with stay-at-home and social distancing guidelines. *Cureus*. 2021;13:e14444.
- Ghafil C, Matsushima K, Ding L, Henry R, Inaba K. Trends in trauma admissions during the COVID-19 pandemic in Los Angeles county, California. *JAMA Netw Open*. 2021;4:e211320.
- Couto RA, Wiener TC, Adams WP. Evaluating postoperative outcomes of patients undergoing elective procedures in an ambulatory surgery center during the COVID-19 pandemic. *Aesthet Surg J*. 2021;41:250–257.
- Chodos M, Sarani B, Sparks A, et al. Impact of COVID-19 pandemic on injury prevalence and pattern in the Washington, DC metropolitan region: a multicenter study by the American College of Surgeons Committee on Trauma, Washington, DC. *Trauma Surg Acute Care Open*. 2021;6:e000659.
- Salottolo K, Caiafa R, Mueller J, et al. Multicenter study of US trauma centers examining the effect of the COVID-19 pandemic on injury causes, diagnoses and procedures. *Trauma Surg Acute Care Open*. 2021;6:e000655.
- Moreland A, Herlihy C, Tynan MA, et al. Timing of state and Territorial COVID-19 stay-at-home orders and changes in population Movement — United States, March 1–May 31, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69:1198–1203.
- Berg GM, Wyse RJ, Morse JL, et al. Decreased adult trauma admission volumes and changing injury patterns during the COVID-19 pandemic at 85 trauma centers in a multistate healthcare system. *Trauma Surg Acute Care Open*. 2021;6:e000642.
- Pelzl CE, Salottolo K, Banton K, et al. COVID-19 and trauma: how social distancing orders altered the patient population using trauma services during the 2020 pandemic. *Trauma Surg Acute Care Open*. 2021;6:e000645.
- Forrester JD, Liou R, Knowlton LM, Jou RM, Spain DA. Impact of shelter-in-place order for COVID-19 on trauma activations: Santa Clara county, California, March 2020. *Trauma Surg Acute Care Open*. 2020;5:e000505.
- Leichtle SW, Rodas EB, Procter L, Bennett J, Schrader R, Aboutanos MB. The influence of a statewide "Stay-at-Home" order on trauma volume and patterns at a level 1 trauma center in the United States. *Injury*. 2020;51:2437–2441.
- Czeisler MÉ, Tynan MA, Howard ME, et al. Public attitudes, behaviors, and beliefs related to COVID-19, stay-at-home orders, nonessential business closures, and public health guidance - United States, New York City, and Los Angeles, May 5-12, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69:751.
- Felix A, Shampine S. Consumer Spending Declines, Shifts in Response to the Pandemic. Federal Reserve Bank of Kansas City. 2021. Available at: <https://www.kansascityfed.org/documents/7613/eb21felixshampine0217.pdf>. Accessed June 10, 2021.
- Trauma Center Levels Explained. American Trauma Society. Available at: <https://www.amtrauma.org/page/traumalevels>. Accessed April 16, 2021.
- Ramgopal S, Dunnick J, Siripong N, Conti KA, Gaines BA, Zuckerman NS. Seasonal, weather, and temporal factors in

- the prediction of admission to a pediatric trauma center. *World J Surg.* 2019;43:2211–2217.
28. Harden JD, Jouvenl J. Crime rose unevenly when stay-at-home orders lifted. The racial disparity is the widest in years. *The Washington Post.* 2020. Available at: <https://www.washingtonpost.com/graphics/2020/local/public-safety/crime-rate-coronavirus/>. Accessed June 10, 2021.
29. Bivens J, Zipperer B. Health insurance and the COVID-19 Shock. Economic Policy Institute. 2020. Available at: <https://files.epi.org/pdf/206003.pdf>. Accessed June 10, 2021.
30. Health Coverage Under the Affordable Care Act: Enrollment Trends and State Estimates. U.S. Department of Health and Human Services. 2021. Available at: <https://aspe.hhs.gov/system/files/pdf/265671/ASPE%20Issue%20Brief-ACA-Related%20Coverage%20by%20State.pdf>. Accessed June 7, 2021.
31. Coleman JR, Burlew CC, Platnick KB, et al. Maintaining trauma care access during the COVID-19 pandemic: an urban, level-1 trauma center's experience. *Ann Surg.* 2020;272:e58–e60.
32. Rhodes HX, Petersen K, Biswas S. Trauma trends during the initial peak of the COVID-19 pandemic in the midst of lockdown: experiences from a rural trauma center. *Cureus.* 2020;12:e9811.
33. DiFazio LT, Curran T, Bilaniuk JW, et al. The impact of the COVID-19 pandemic on hospital admissions for trauma and acute care surgery. *Am Surg.* 2020;86:901–903.
34. Devarakonda AK, Wehrle CJ, Chibane FL, Drevets PD, Fox ED, Lawson AG. The effects of the COVID-19 pandemic on trauma Presentations in a level one trauma center. *Am Surg.* 2021;87:686–689. 10.1177/0003134820973715.
35. Abdallah HO, Zhao C, Kaufman E, et al. Increased firearm injury during the COVID-19 pandemic: a hidden urban burden. *J Am Coll Surg.* 2021;232:159–168.e3.
36. Yeates EO, Grigorian A, Barrios C, et al. Changes in traumatic mechanisms of injury in Southern California related to COVID-19: penetrating trauma as a second pandemic. *J Trauma Acute Care Surg.* 2021;90:714–721.
37. NICS Firearm Checks: Month/Year. Federal Bureau of Investigation. Available at: https://www.fbi.gov/file-repository/nics_firearm_checks_-_month_year.pdf/view. Accessed June 12, 2021.
38. Sutherland M, McKenney M, Elkbulli A. Gun violence during COVID-19 pandemic: paradoxical trends in New York City, Chicago, Los Angeles and Baltimore. *Am J Emerg Med.* 2021;39:225–226.
39. Hatchimonji JS, Swendiman RA, Seamon MJ, Nance ML. Trauma does not quarantine: violence during the COVID-19 pandemic. *Ann Surg.* 2020;272:e53–e54.
40. Kim DY, Phillips SW. When COVID-19 and guns meet: a rise in shootings. *J Crim Justice.* 2021;73:101783.
41. Sammy I, Lecky F, Sutton A, Leaviss J, O'Cathain A. Factors affecting mortality in older trauma patients-A systematic review and meta-analysis. *Injury.* 2016;47:1170–1183.
42. Osler T, Cook A, Gance LG, et al. The differential mortality of Glasgow Coma Score in patients with and without head injury. *Injury.* 2016;47:1879–1885.
43. Mikhail JN, Nemeth LS, Mueller M, et al. The association of race, socioeconomic status, and insurance on trauma mortality. *J Trauma Nurs.* 2016;23:347–356.
44. Van Ditschuijzen JC, Van Den Driessche CRL, Sewalt CA, Van Lieshout EMM, Verhofstad MHJ, Den Hartog D. The association between level of trauma care and clinical outcome measures: a systematic review and meta-analysis. *J Trauma Acute Care Surg.* 2020;89:801–812.
45. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Chan L. The effect of trauma center designation and trauma volume on outcome in specific severe injuries. *Ann Surg.* 2005;242:512–519.
46. Fitch CJL, Albini PT, Patel AY, et al. Blunt versus penetrating trauma: is there a resource intensity discrepancy? *Am J Surg.* 2019;218:1201–1205.
47. Tingey JL, Bentley JA, Hosey MM. COVID-19: understanding and mitigating trauma in ICU survivors. *Psychol Trauma.* 2020;12:S100–S104.
48. Sen-Crowe B, Sutherland M, McKenney M, Elkbulli A. A closer look into global hospital beds capacity and resource shortages during the COVID-19 pandemic. *J Surg Res.* 2021;260:56–63.
49. Ranney ML, Griffeth V, Jha AK. Critical supply shortages - the need for ventilators and personal protective equipment during the Covid-19 pandemic. *N Engl J Med.* 2020;382:e41.
50. HCA Healthcare to Provide up to 1,000 Ventilators as Part of Public-Private Collaboration to Battle COVID-19. HCA Healthcare. 2020. Available at: <https://investor.hcahealthcare.com/news/news-details/2020/HCA-Healthcare-to-Provide-up-to-1000-Ventilators-as-Part-of-Public-Private-Collaboration-to-Battle-COVID-19/default.aspx>. Accessed September 14, 2021.
51. Sen-Crowe B, McKenney M, McKenney M, Elkbulli A. Challenges associated with blood banks and blood donations during the COVID-19 pandemic. *Am J Emerg Med.* 2021;43:281–282.
52. Protect Access To Long Term Care For Vulnerable Residents. American Health Care Association and National Center for Assisted Living. Available at: https://d3dkdvqff0zqx.cloudfront.net/groups/ahca/attachments/protect%20access%20to%20long%20term%20care_ib.pdf. Accessed June 20, 2021.
53. Fakhry SM, Martin B, Al Harakeh H, Norcross ED, Ferguson PL. Proportional costs in trauma and acute care surgery patients: dominant role of intensive care unit costs. *J Am Coll Surg.* 2013;216:607–616.
54. Lanzarotti S, Cook CS, Porter JM, Judkins DG, Williams MD. The cost of trauma. *Am Surg.* 2003;69:766–770.
55. Velopulos CG, Enwerem NY, Obirieze A, et al. National cost of trauma care by payer status. *J Surg Res.* 2013;184:444–449.
56. Corallo B, Rudowitz R. Analysis of Recent National Trends in Medicaid and CHIP Enrollment. Kaiser Family Foundation. 2021. Available at: <https://www.kff.org/coronavirus-covid-19/issue-brief/analysis-of-recent-national-trends-in-medicaid-and-chip-enrollment/>. Accessed June 20, 2021.
57. Vali Y, Rashidian A, Jalili M, Omidvari AH, Jeddian A. Effectiveness of regionalization of trauma care services: a systematic review. *Public Health.* 2017;146:92–107.
58. Elkbulli A, Herrera M, Awan M, Ellassad C. Striving towards an effective emergency preparedness and disaster management response: Lessons learned and future directions. *Am J Emerg Med.* 2021;50:804–805. <https://doi.org/10.1016/j.ajem.2021.03.036>.
59. Sen-Crowe B, McKenney M, Elkbulli A. COVID-19 response and containment strategies in the US, South Korea, and Iceland: lessons learned and future directions. *Am J Emerg Med.* 2020;38:1537–1539.
60. Kaufman EJ, Ong AW, Cipolle MD, et al. The impact of COVID-19 Infection on outcomes after injury in a state trauma system. *J Trauma Acute Care Surg.* 2021;91:559–565. <https://doi.org/10.1097/TA.0000000000003310>.
61. Yeates EO, Grigorian A, Schellenberg M, et al. COVID-19 in trauma: a propensity-matched analysis of COVID and non-COVID trauma patients. *Eur J Trauma Emerg Surg.* 2021;47:1335–1342. <https://doi.org/10.1007/s00068-021-01x699-9>.