Check for updates

The Effects of the COVID-19 Pandemic on Penetrating Neurotrauma at a Level 1 Trauma Center

George L. Yang[1,2,5], Mark D. Johnson[1,2,5], Daniel Solomon[5], Andrew M. Ferguson[3,5], Reid A. Johnson[6], Christina Gerges[8], James M. Wright[8], Ann M. Parr[7], Laura B. Ngwenya[1,2,4,5], in affiliation with the Council of State Neurosurgical Societies (CSNS)

■ BACKGROUND/OBJECTIVE: **The COVID-19 pandemic has had a profound impact on the global delivery of health care. Recent data suggest a possible impact of the pandemic on patterns of neurotrauma. The aim was to assess the impact of the pandemic on the incidence of neurotrauma, with a focus on cranial gunshot wounds (cGSWs) at a large Midwestern level 1 trauma center.**

■ METHODS: **We conducted a retrospective review of our trauma registry from March through September 2020 and compared it to the same months in 2019. Odds ratios were utilized to assess for differences in patient demographics, injury characteristics, rates of neurotrauma, and rates of cGSWs.**

■ RESULTS: **A total of 1188 patients presented with neurotrauma, 558 in 2019 and 630 in 2020. The majority of patients were male (71.33% in 2019; 68.57% in 2020) and Caucasian (78.67% in 2019; 75.4% in 2020). Patients presented with cGSWs more frequently in 2020 (n = 49, 7.78%) than in 2019 (n = 25, 4.48%). The odds of suffering a cGSW in 2020 was 73.6% higher than those in 2019 (95% confidence interval = [1.0871, 2.7722]; *P* = 0.0209). The etiology of such injury was most commonly assault (n = 16, 21.62% in 2019; n = 34, 45.95% in 2020), followed by self-inflicted injury (n = 4, 5.41% in 2019; 12, 16.22% in 2020).**

■ CONCLUSIONS: **Despite the government-mandated shutdown, we observed an increase in the number of neurotrauma cases in 2020. There was a significant increase in the incidence cGSWs in 2020, with an increase in assaults and self-inflicted injuries. Further investigation into socioeconomic factors for the observed increase in cGSWs is warranted.**

INTRODUCTION

The first cases of COVID-19 were reported in Ohio on March 9, 2020. That day, a state of emergency was declared, with a stay-at-home order issued in Ohio on March 23 to slow the viral spread. The COVID-19 pandemic has stressed our health care system, with heavily publicized and politicized strains on finite resources. Shortages in personal protective equipment, ventilators, personnel, and vaccine stock have been recognized with concerted responses by governments and health care organizations.[1,2] These challenges have pushed organizations to develop strategies for responding to future situations when health care resources may be limited.[3] Characterization of health care utilization in times of crisis is a critical aspect of developing an informed crisis response during a pandemic with stay-at-home orders. One unexpected observed result of the pandemic was a shift in the patterns of neurotrauma. A few

Key words
- COVID-19
- Cranial gunshot wounds
- Neurotrauma
- Pandemic

Abbreviations and Acronyms
cGSWs: Cranial gunshot wounds
GCS: Glasgow Coma Scale
OR: Odds ratio
PMH: Past medical history

From the [1]Department of Neurosurgery, University of Cincinnati Medical Center; [2]Collaborative for Research on Acute Neurological Injury (CRANI), [3]Department of Psychiatry, and [4]Department of Neurology & Rehabilitation Medicine, University of Cincinnati; and [5]University of Cincinnati College of Medicine, Cincinnati, Ohio; [6]University of Minnesota Medical School, and [7]Department of Neurosurgery, Stem Cell Institute, University of Minnesota, Minneapolis, Minnesota; and [8]Department of Neurological Surgery, Oregon Health and Science University, Portland, Oregon, USA

*To whom correspondence should be addressed: George L. Yang, M.D.
[E-mail: yangge@ucmail.uc.edu]*

*Citation: World Neurosurg. (2022) 164:e530-e539.
https://doi.org/10.1016/j.wneu.2022.05.001*

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

studies have examined the rates of neurotrauma in 2020, most of which observed the incidence of neurotrauma in major metropolitan areas. One such study looked at the rates of neurotrauma in New York City. Using institutional data on neurotrauma admissions at Mount Sinai Morningside, the authors found a significant decrease in the number of neurotrauma cases during the early parts of the stay-at-home period.[4] Ryder Trauma Center in Miami reported similar findings, showing a significant decline in neurotrauma admissions at the beginning of the pandemic.[5] The authors hypothesized various reasons for these findings, including travel restrictions, business closures, and increases in psychosocial stress.[4,5]

While some centers have reported an overall decrease in the number of neurotrauma cases, there have been reports of increased rates of cranial gunshot wounds (cGSWs) during this period. For example, Miami reported a 12% proportional increase of cGSWs to total neurotrauma cases.[5] The increase in gun violence in 2020 has been attributed primarily to psychosocial determinants of the pandemic.[6] This is consistent with known worsening of mental health disorders and suicidal tendencies during times of major economic crises and natural disasters.[7-9]

As earlier studies have assessed specific regional trends, more studies are needed to generalize the pandemic's effects on the incidence of neurotrauma. This work aimed to assess the impact of the pandemic on rates of neurotrauma at a large Midwestern level 1 trauma center responsible for providing trauma care for a population of approximately 2.2 million people. Specifically, we compare the impact of stay-at-home orders on cGSW incidence and present evidence to guide future policy management in times of mandated lockdown.

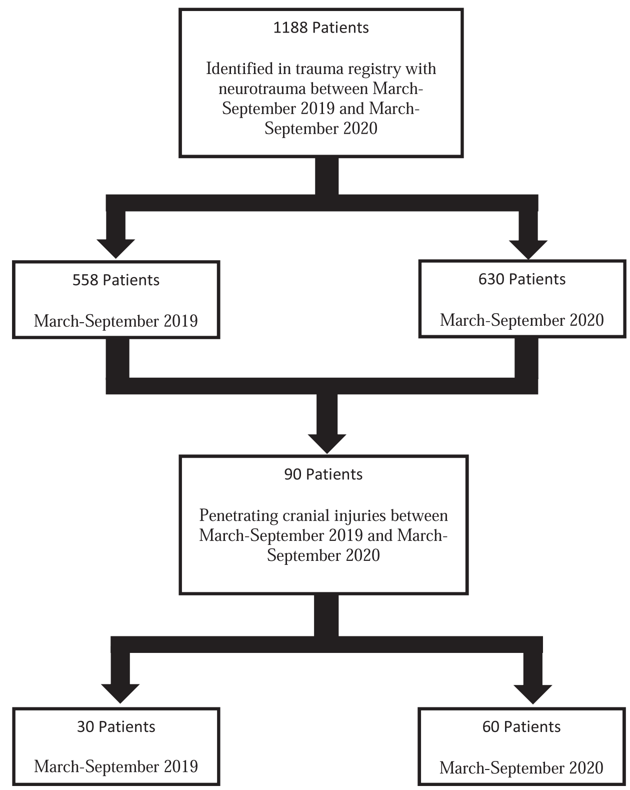

Figure 1. Flow diagram of patient selection.

METHODS

A retrospective chart review of a prospectively maintained institutional trauma registry was performed using 2 distinct periods for comparison: March 2019—September 2019 and March 2020 through September 2020. The 7-month period from March to September 2020 represents our study's time frame of interest. Neurotrauma was defined as cerebral, spinal, or ocular injuries in patients at presentation with a known traumatic mechanism. International Classification of Diseases—10 codes were used to query the registry (**Supplementary Table 1**). This query yielded 558 patients in 2019 and 630 patients in 2020, for a total of 1188 patients who presented to the emergency department. Of these patients, 90 had penetrating injuries, with 51 presenting following cGSWs (**Figure 1**).

Our study protocol is consistent with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines and received approval from our institutional review board with a waiver of the requirement to obtain informed consent and authorization for the use of protected health information as the research was determined to present no more than minimal risk.

For all neurotrauma patients, we extracted the following variables from the registry: age, race, gender, initial hospital Glasgow Coma Scale (GCS) score, head Abbreviated Injury Scale score, Injury Severity Score, mortality, and cause of trauma. Mechanisms of injury were categorized as falls, motor vehicle accidents, motorcycle crashes, GSWs, bicycle accidents, struck pedestrians, and "other." To further characterize penetrating neurotrauma, individual electronic health records were reviewed for additional variables, including motive, pertinent medical history, pupillary response on arrival, initial/discharge GCS score, discharge disposition, and survival at 6 months after injury. For patients with penetrating neurotrauma, the past medical history (PMH), including alcohol use, drug use, terminal illness, history of depression, or any other psychiatric diagnosis, was also recorded. Computed tomography characteristics included the presence of intraventricular hemorrhage, basal cistern compression, injury anatomy, presence of multiple penetrating injuries, bullet trajectory, and transventricular injury. Bullet trajectories were classified as tangential, penetrating, and perforating. A tangential trajectory was defined as oblique impact without bullet entry into the parenchyma, a penetrating trajectory was defined as a parenchymal injury with a retained missile, and a perforating trajectory was defined as a through-and-through parenchymal injury with identifiable cranial entry and exit wounds.

To assess total and penetrating neurotrauma changes between 2019 and 2020, groupings were analyzed for between-group differences as median $\pm$ interquartile range for continuous variables and percentage totals for categorical variables. To investigate the odds of presentation with any neurotrauma in 2020, odds ratios (ORs) were calculated for categorical variables. Demographics and injury characteristics were also examined for ORs with significance verified utilizing Fisher's exact test. Additionally, ORs were calculated for the PMH to investigate the odds conferred for presentation with penetrating neurotrauma during the period. A P value < 0.05 was determined to be statistically significant. Analysis was performed using SAS, version 9.4 (SAS, Cary, North Carolina, USA).

RESULTS

Total Neurotrauma

We observed 558 neurotrauma cases in 2019 and 630 in 2020 (OR = 1.129 [1.0071, 1.2657]). The mean age of patients identified was 53.0 years (range = 14–99) in 2019 and 48.9 years (range = 14–101) in 2020. There was no statistical significance in the racial makeup of the trauma population during the study period. Men comprised 71.3% of the patients identified in 2019 and 68.6% in 2020 (P = 0.03). Injury severity did not differ between study periods, with no differences observed in the initial hospital GCS score, head Abbreviated Injury Scale score, Injury Severity Score, or mortality between the 2 groups (Table 1). Significant differences were noted in the mechanism of injury between groups (Figure 2). Patients in the 2020 group were less likely to have had cranial neurotrauma as a result of a fall (42.3% vs. 34.3%) (OR = 0.7119 [0.5627, 0.9005]) and more likely as a result of the GSW (4.48% vs. 7.78%) (OR = 1.7981 [1.0951, 2.9523]).

cGSW Characteristics

Comparisons for penetrating cranial injuries are summarized in Table 2. The mean age was 30.1 years in 2019 and 31.9 years in 2020. There were no significant differences between cGSW rates in either males or females. The racial distribution of

Table 1. Neurotrauma Demographics 2019 versus 2020

Characteristic	2019 n (%)	2020 n (%)	Fisher's Table P (pr ≤ P) OR [95% CI]
Number of traumas	558	630	**1.1290 [1.0071, 1.2657]**
Age mean (Min-Max)	53.04 (14—99)	48.91 (14—101)	—
Race			**<0.0001 (0.4821)**
White	439 (78.67)	475 (75.40)	0.8307 [0.6330, 1.0902]
Black	89 (15.95)	121 (19.21)	1.2527 [0.9270, 1.6928]
Asian	7 (1.25)	5 (0.79)	0.6297 [0.1987, 1.9955]
Hispanic	13 (2.33)	19 (3.02)	1.3037 [0.6378, 2.6646]
Other	10 (1.79)	10 (1.59)	0.8839 [0.3651, 2.1396]
Gender			**0.0297 (0.3113)**
Male	398 (71.33)	432 (68.57)	0.8771 [0.6838, 1.1250]
Female	160 (28.67)	198 (31.43)	1.1401 [0.8889, 1.4623]
Initial hospital GCS total mean [95% CI]	11.84 [3.03, 20.65]	11.54 [2.31, 20.78]	–
Head AIS mean [95% CI]	3.31 [1.14, 5.48]	3.35 [1.12, 5.59]	–
ISS mean [95% CI]	20.11 [-4.02, 44.23]	20.57 [-4.59, 45.73]	–
Outcome			**0.0532 (0.4908)**
Survived	481 (96.20)	551 (87.60)	1.1308 [0.8067, 1.5853]
Deceased	77 (13.80)	78 (12.40)	0.8843 [0.6308, 1.2396]
Mechanism of injury			**<0.0001 (–)**
Fall	236 (42.29)	216 (34.29)	**0.7119 [0.5627, 0.9005]**
MVA	122 (21.86)	143 (22.70)	1.0494 [0.7979, 1.3801]
MCC	58 (10.39)	64 (10.16)	0.9748 [0.6699, 1.4185]
GSW	25 (4.48)	49 (7.78)	**1.7981 [1.0951, 2.9523]**
Bicycle	10 (1.79)	8 (1.27)	0.7048 [0.2762, 1.7985]
Pedestrian	20 (3.58)	18 (2.86)	0.7912 [0.4142, 1.5114]
Other	87 (15.61)	132 (20.94)	**4.0850 [2.7482, 6.0723]**

Bold values indicate results were significant.
OR, odds ratio; CI, confidence interval; GCS, Glasgow Coma Scale; AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; GSW, gunshot wound; MVA, motor vehicle accidents; MCC, motorcycle crash.

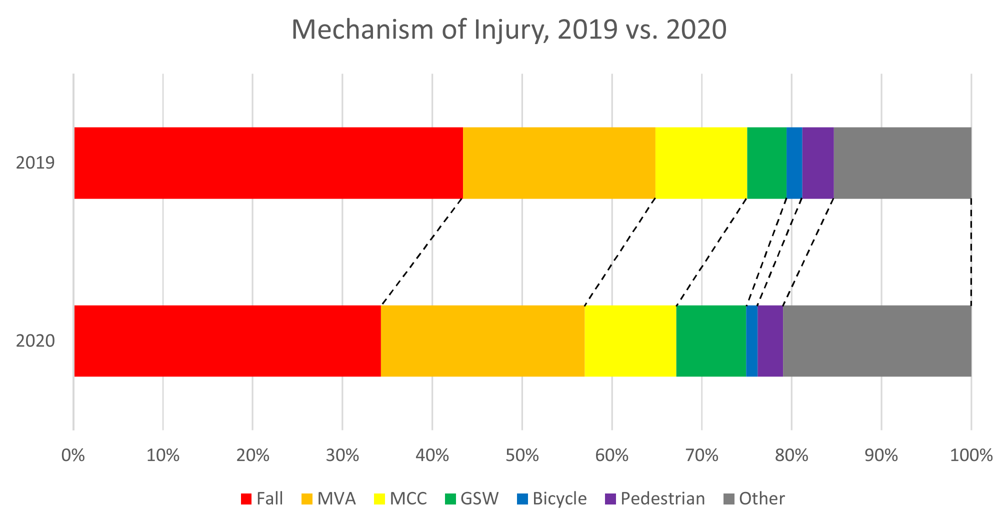

Figure 2. Stacked bar chart of mechanisms of injury for neurotrauma, 2019 versus 2020.

penetrating cranial injuries significantly differed across both periods (P = 0.0134), with black people presenting with the highest proportion of penetrating cranial injuries (50.0% in 2019 and 48.3% in 2020). In contrast, black people only made up 15.95% in 2019 and 19.21% in 2020 of the total neurotrauma admissions. The most common motive for cGSWs in both years was assault (56.7% vs. 60.0%), followed by self-inflicted (13.3% vs. 20.0%) and accidental (20.0% vs. 18.3%) injuries. The difference in motive observed between 2019 and 2020 was statistically significant (P = 0.0043). The PMH was not associated with increased odds of presenting with a cGSW. Of the penetrating injuries, 44.4% of patients had imaging for review with intracranial findings. The remaining patients did not have imaging obtained upon arrival, likely due to clinical instability or death on arrival. There were no significant differences between groups regarding intraventricular hemorrhage, basal cistern compression, or ventricle involvement. There were no significant differences between mean arrival and discharge GCS scores (Table 2). There was a statistically significant difference in the proportion of patients presenting with bilaterally reactive pupils (P = 0.0025), increasing from 48.3% in 2019 to 59.3% in 2020. This was an observed increase in the rate of discharge home from 27.6% in 2019 to 37.3% in 2020 (P = 0.0002). This correlated with an increase in survival rate at 6 months from 41.4% in 2019 to 54.2% in 2020 (P = 0.0188).

DISCUSSION

Traumatic injuries, intentional and unintentional, are the leading cause of death in individuals younger than 45 years of age and the third leading cause of death across all age groups.[10] There were nearly 61,000 traumatic brain injury–related deaths in 2019.[11] Our data demonstrate a 12.9% increase in neurotrauma rates in the equivalent 6-month period between 2019 and 2020. We found that the proportion of mechanisms of injury changed with the pandemic, with a decrease in falls and an increase in penetrating neurotrauma (Table 1). The change in the proportion of falls may be secondary to social distancing recommendations, with fewer citizens traveling out of their homes for recreation and work. Since the pandemic, 71% of Americans have transitioned to work from home, a 51% increase when compared to rates prior to the pandemic.[12] No significant differences in the mechanism of injury were noted between age groups.

Significant differences in the discharge disposition (P = 0.0002) and survival at 6 months (P = 0.0188) were observed. The 2020 group had a higher proportion of patients discharged home with penetrating injuries. The reason for this is unclear, given a lack of significant differences between groups in mean arrival GCS score, discharge GCS score, and imaging characteristics. One hypothesis for the increased rates of discharge home is that there were barriers to facility placement in 2020 due to restrictions on family visitation, facility capacity, nursing home capacity, and fear of viral exposure.[13-15] Another possible explanation is that the injury patterns seen in 2020 were less severe than those seen in 2019. We did note significantly more patients in 2020 with bilaterally reactive pupils, which is a favorable prognostic marker. However, we did not find significant differences in radiographic and clinical characteristics of injury severity due to the low number of events. In our study, we collected the discharge GCS score; however, better characterization of a patient's functional capacity to carry out activities of daily living, such as the modified Rankin Scale, may be helpful to explain differences in discharge disposition further.

In addition to the increase in penetrating injuries, a significant increase in the mechanisms of assault and self-inflicted injuries was seen in 2020, with rates doubling and tripling, respectively (Table 2). The increase in total and self-inflicted penetrating injuries seen in our cohort could be secondary to the psychosocial effects of mandatory isolation and associated increased risk of

Table 2. Penetrating Cranial Injuries Demographics 2019 versus 2020

Characteristic	Full Sample (n = 90)	2019 (n = 30) (%)	2020 (n = 60) (%)	*P*-value Fisher's Table (pr ≤ *P*)
Age mean (Min-Max)	31.32 (14—86)	30.10 (16—63)	31.93 (14—86)	–
Gender				0.0779 (0.0926)
Female	6 (6.67)	4 (13.33)	2 (3.33)	
Male	84 (93.33)	26 (86.67)	58 (96.67)	
Race				0.0134 (0.7096)
White	39 (43.33)	12 (40.00)	27 (45.00)	
Black	44 (48.89)	15 (50.00)	29 (48.33)	
Asian	1 (1.11)	1 (3.33)	0	
Hispanic	5 (5.56)	2 (6.67)	3 (5.00)	
Other	1 (1.11)	0	1 (1.67)	
Motive				0.0043 (0.3323)
Assault	53 (58.89)	17 (56.67)	36 (60.00)	
Self	16 (17.78)	4 (13.33)	12 (20.00)	
Accident	17 (18.89)	6 (20.00)	11 (18.33)	
Unknown/other	4 (4.44)	3 (10.00)	1 (1.67)	
History*	n	n	n	OR (*P*)
Alcohol	5	2	3	0.74 (0.75)
Drug	5	2	3	0.74 (0.75)
Terminal	0	0	0	–
Depression	13	4	9	1.15 (0.83)
Psychiatric	13	4	9	1.15 (0.83)
None	40	15	25	0.71 (0.45)
Unknown	26	8	18	1.18 (0.74)
Pupil response on arrival				0.0025 (0.2959)
Both reactive	49 (55.68)	14 (48.28)	35 (59.32)	
None reactive	27 (30.68)	13 (44.83)	14 (23.73)	
One reactive	4 (4.55)	1 (3.45)	3 (5.08)	
Globe rupture	7 (7.95)	1 (3.45)	6 (10.17)	
Unknown	1 (1.14)	0	1 (1.69)	
Neurosurgery GCS mean [95% CI]	9.27 [-1.21,19.74]	9.47 [-1.79,20.72]	9.17 [-1.12,19.46]	—
Discharge GCS mean [95% CI]	10.32 [-0.61,21.24]	9.54 [-1.94,21.01]	10.70 [0.07,21.34]	–
Discharge disposition				0.0002 (0.3418)
Home	30 (34.09)	8 (27.59)	22 (37.29)	
SNF	1 (1.14)	0	1 (1.69)	
IPR	1 (1.14)	1 (3.45)	0	
LTACH	7 (7.95)	3 (10.34)	4 (6.78)	
Expired	23 (26.14)	11 (37.93)	12 (20.34)	
Withdrawal of care	9 (10.23)	2 (6.90)	7 (11.86)	

Continues

Table 2. Continued

Characteristic	Full Sample (n = 90)	2019 (n = 30) (%)	2020 (n = 60) (%)	*P*-value Fisher's Table (pr ≤ *P*)
Survival at 6 months				0.0188 (0.3670)
Yes	44 (50.00)	12 (41.38)	32 (54.24)	
No	33 (37.50)	14 (48.28)	19 (32.20)	
Unknown	11 (12.50)	3 (10.34)	8 (13.56)	

CI, confidence interval; GCS, Glasgow Coma Scale; SNF, skilled nursing facility; IPR, inpatient rehab; LTACH, long term acute care hospital.
*Responses are not exclusive.

suicide. Additional authors have noted high levels of distress and significant increases in depressive/anxious symptoms in several countries during the pandemic.[6,16] The increased rates of observed assaults are less well theorized, with possible associations between multiple social and financial stressors during the pandemic. Another contributory factor may be increased firearm injuries and sales in the pandemic. A study conducted at Penn Presbyterian Medical Center noted a 141% increase in firearm injury during the pandemic.[17] In addition, pandemic fears and social unrest related to police violence led to record gun sales.[18]

We observed an increase in neurotrauma admissions compared to similar studies where a decrease in neurotrauma admissions was noted.[4,5] The decreases observed at Mount Sinai Morningside may be attributed to a shift in presenting mechanisms of injury. In both the pre-COVID and post-COVID periods, mechanical falls were the most significant contributor to neurotrauma, but we observed a decrease in the proportion of falls (Table 1). The difference between what was observed in our region and the previous studies may be attributed to hospital characteristics, study region, and patient population.[4,5] While Mount Sinai Morningside is a level 2 trauma center in a major metropolitan setting, its prepandemic volumes were lower than those observed at our level 1 trauma center (1188 encounters in our 2019 and 2020 time periods).[4] New York City was also much more restricted in terms of people's movements during their shutdown than over the same period in Ohio. In addition, it was reported that many individuals left the city for other parts of the country prior to their shutdown. Ryder Trauma Center in Miami, FL, is a level 1 trauma center; however, the study period was truncated from the onset of the stay-at-home period (March 1, 2020, to April 30, 2020). Our study was performed after the conclusion of the stay-at-home period (May 29, 2020), which allowed for the analysis of trends across multiple months.[5] Therefore, we believe our study contributes to previous publications that investigated neurotrauma during the stay-at-home period. Our institution looks into a Midwest level 1 trauma center that services a mix of urban, suburban, and rural communities in its catchment area, compared to other large urban studies.

The increased rate of neurotrauma in our cohort highlights the need for hospitals to anticipate and be prepared for increased encounters when another pandemic arises despite alterations to activity. One significant improvement in care delivery that occurred due to the pandemic was the widespread adoption of telemedicine.[19] However, the severity of the cases at our institution reinforces the importance of having adequate neurosurgical coverage at trauma centers even during a high resource utilization time such as a pandemic. In addition, the rates of trauma, especially neurotrauma, during a stay-at-home period can have a more considerable impact than solely hospital coverage and data reporting. Policymakers can use these data to anticipate what regions and health care centers will be expected to see an increase in population number and resource utilization during situations in which large amounts of the population are required to quarantine. An example is the significant exodus of people from heavily populated urban centers to more suburban and rural regions. The increased rates of cGSWs can potentially influence gun law policy and represent the need for accessible and affordable mental health resources.

Limitations

Our study is not without limitations. First, our data include data from a single institution in a metropolitan Midwestern city that is the only level one trauma center in this region, so presumably, our center receives the most severe cases, including penetrating neurotrauma. This impacts the generalizability of our study for primarily urban environments but offers a generalizable population study for other Midwest cities. Additionally, it is unknown how many neurotrauma patients expired at the scene or arrived at outside institutions with unsurvivable injuries. Many patients in our registry often had incomplete data regarding specific variables, such as the PMH and psychiatric history, as they often presented under trauma aliases. Our study also includes data only from the year immediately prior to and the first year of the pandemic, limiting our ability to determine if this was an actual change in cGSW patterns. Finally, the retrospective nature of our study introduces some inherent limitations, such as information bias. Information bias was controlled by a standardized online data collection tool and procedure, utilizing a working dictionary to homogenize data collection in the electronic health record. Duplicate charts and other hospital electronic medical records were checked to minimize associated errors.

CONCLUSION

The COVID-19 pandemic, with its stay-at-home orders and changes in behavior, is associated with significant changes in patterns of neurotrauma, with an observed increase in patient volumes and incidence of cGSWs at our institution. Psychosocial aspects of the lockdowns and the economic impact of the pandemic may have contributed to increased rates of assault and self-inflicted penetrating injuries. While other centers have published decreased rates of neurotrauma, our experience highlights the importance of continued preservation of resources and flexibility for rapid expansion of hospital capacity in the event of a future pandemic or situation when health care resources may be limited. Understanding health care utilization in times of crisis is critical to developing response plans in the future, which may need to be tailored to the geographic region of interest.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

George L. Yang: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Mark D. Johnson:** Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Daniel Solomon:** Conceptualization, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Andrew M. Ferguson:** Methodology, Formal analysis, Writing – review & editing. **Reid A. Johnson:** Conceptualization, Writing – review & editing. **Christina Gerges:** Conceptualization, Writing – review & editing. **James M. Wright:** Conceptualization, Writing – review & editing. **Ann M. Parr:** Conceptualization, Writing – review & editing. **Laura B. Ngwenya:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration.

REFERENCES

1. Rosenbaum L. Facing COVID-19 in Italy—ethics, logistics, and therapeutics on the epidemic's front line. *N Engl J Med*. 2020;382:1873-1875.

2. White DB, Lo B. A framework for rationing ventilators and critical care beds during the COVID-19 pandemic. *JAMA*. 2020;323:1773-1774.

3. Butler CR, Wong SPY, Wightman AG, O'Hare AM. US clinicians' experiences and perspectives on resource limitation and patient care during the COVID-19 pandemic. *JAMA Netw Open*. 2020;3:e2027315.

4. Lara-Reyna J, Yaeger KA, Rossitto CP, et al. "Staying Home"-early changes in patterns of neurotrauma in New York city during the COVID-19 pandemic. *World Neurosurg*. 2020;143:e344-e350.

5. Figueroa JM, Boddu J, Kader M, et al. The effects of lockdown during the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic on neurotrauma-related hospital admissions. *World Neurosurg*. 2021;146:e1-e5.

6. Gunnell D, Appleby L, Arensman E, et al, COVID-19 Suicide Prevention Research Collaboration. Suicide risk and prevention during the COVID-19 pandemic. *Lancet Psychiatry*. 2020;7:468-471.

7. Chaves C, Castellanos T, Abrams M, Vazquez C. The impact of economic recessions on depression and individual and social well-being: the case of Spain (2006-2013). *Soc Psychiatry Psychiatr Epidemiol*. 2018;53:977-986.

8. Beaglehole B, Mulder RT, Frampton CM, Boden JM, Newton-Howes G, Bell CJ. Psychological distress and psychiatric disorder after natural disasters: systematic review and meta-analysis. *Br J Psychiatry*. 2018;213:716-722.

9. Brooks SK, Webster RK, Smith LE, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet*. 2020;395:912-920.

10. Centers for Disease Control and Prevention. National vital statistics reports. Deaths: leading Causes for 2017. https://www.cdc.gov/nchs/data/nvsr/nvsr68/nvsr68_06-508.pdf. Accessed August 15, 2021.

11. Centers for Disease Control and Prevention. National center for health statistics: mortality data on CDC WONDER 2019. https://wonder.cdc.gov/mcd.html. Accessed August 15, 2021.

12. Parker K, Horowitz JM, Minkin R. How coronavirus has changed the way Americans work. Pew research center's social & demographic trends Project. https://www.pewresearch.org/social-trends/2020/12/09/how-the-coronavirus-outbreak-has-and-hasnt-changed-the-way-americans-work/#:∼:text=Only%20one%2Din%2Dfive%20say,new%20Pew%20Research%20Center%20survey; 2021, May 25. Accessed February 16, 2022.

13. Shao C. The COVID trolley dilemma. *Am J Surg*. 2020;220:545-549.

14. Birkmeyer JD, Barnato A, Birkmeyer N, Bessler R, Skinner J. The impact of the COVID-19 pandemic on hospital admissions in the United States. *Health Aff (Millwood)*. 2020;39:2010-2017.

15. Deschepper M, Eeckloo K, Malfait S, Benoit D, Callens S, Vansteelandt S. Prediction of hospital bed capacity during the COVID-19 pandemic. *BMC Health Serv Res*. 2021;21:468.

16. United Nations. COVID-19 and the need for action on mental health. https://unsdg.un.org/sites/default/files/2020-05/UN-Policy-Brief-COVID-19-and-mental-health.pdf. Accessed August 15, 2021.

17. 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.

18. Beckett L. Americans have bought record 17m guns in year of unrest, analysis finds. The Guardian https://www.theguardian.com/us-news/2020/oct/29/coronavirus-pandemic-americans-gun-sales; 2020, October 30. Accessed August 15, 2021.

19. Wright J, Elder T, Gerges C, et al, in affiliation with the Council of State Neurosurgical Societies (CSNS). A systematic review of telehealth for the delivery of emergent neurosurgical care. *J Telemed Telecare*. 2021;27:261-268.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 17 April 2022; accepted 3 May 2022

Citation: World Neurosurg. (2022) 164:e530-e539.
https://doi.org/10.1016/j.wneu.2022.05.001

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

SUPPLEMENTARY DATA

Supplementary Table 1. Trauma Registry International Classification of Diseases—10 Codes

Category	Category Descriptor	Etiology, Anatomic Site, Severity, Extension
T54	Toxic effect of corrosive substances	3X1A
T65	Toxic effect of other and unspecified substances	891A
T71	Asphyxiation	162A
V00	Pedestrian conveyance accident	131A
V03	Pedestrian injured in collision with a car, pick-up truck, or van	00XA, 10XA, 19XA, 99XA
V04	Pedestrian injured in collision with a heavy transport vehicle or bus	00XA, 10XA
V05	Pedestrian injured in collision with a railway train or railway vehicle	00XA, 10XA, 90XA
V09	Pedestrian injured in other and unspecified transport accidents	20XA, 29XA
V11	A pedal cycle rider injured in collision with the other pedal cycle	0XXA
V13	A pedal cycle rider injured in collision with a car, pick-up truck, or van	4XXA
V14	A pedal cycle rider injured in collision with a heavy transport vehicle or bus	4XXA
V17	A pedal cycle rider injured in collision with a fixed or stationary object	4XXA
V18	A pedal cycle rider injured in noncollision transport accident	0XXA, 4XXA
V19	A pedal cycle rider injured in other and unspecified transport accidents	49XA
V20	A motorcycle rider injured in collision with a pedestrian or animal	0XXA, 4XXA
V22	A motorcycle rider injured in collision with a two- or three-wheeled motor vehicle	4XXA
V23	A motorcycle rider injured in collision with a car, pick-up truck, or van	4XXA, 5XXA, 9XXA.
V24	A motorcycle rider injured in collision with a heavy transport vehicle or bus	4XXA
V27	A motorcycle rider injured in collision with a fixed or stationary object	0XXA, 4XXA, 5XXA
V28	A motorcycle rider injured in noncollision transport accident	0XXA, 1XXA, 4XXA, 5XXA
V29	A motorcycle rider injured in other and unspecified transport accidents	40XA, 9XXA,
V43	A car occupant injured in collision with a car, pick-up truck, or van	51XA, 52XA, 53XA, 62XA, 63XA, 92XA
V44	A car occupant injured in collision with a heavy transport vehicle or bus	5XXA, 6XXA, 9XXA
V47	A car occupant injured in collision with a fixed or stationary object	0XXA, 1XXA, 5XXA, 6XXA
V48	A car occupant injured in noncollision transport accident	1XXA, 2XXA, 4XXA, 5XXA, 6XXA, 9XXA
V49	A car occupant injured in other and unspecified transport accidents	40XA, 49XA, 50XA, 50XA, 88XA, 9XXA
V53	An occupant of a pick-up truck or van injured in collision with a car, pick-up truck, or van	5XXA, 6XXA,
V54	An occupant of a pick-up truck or van injured in collision with a heavy transport vehicle or bus	5XXA, 6XXA
V57	An occupant of a pick-up truck or van injured in collision with a fixed or stationary object	5XXA, 6XXA
V58	An occupant of a pick-up truck or van injured in noncollision transport accident	5XXA, 6XXA
V59	An occupant of a pick-up truck or van injured in other and unspecified transport accidents	40XA, 50XA, 9XXA
V68	An occupant of a heavy transport vehicle injured in noncollision transport accident	4XXA, 6XXA
V80	An animal rider or occupant of an animal-drawn vehicle injured in transport accident	010A, 918A
V84	An occupant of a special vehicle mainly used in agriculture injured in transport accident	0XXA, 5XXA
V85	An occupant of a special construction vehicle injured in transport accident	5XXA
V86	An occupant of a special all-terrain or other off-road motor vehicle injured in transport accident	05XA, 09XA, 55XA, 56XA, 59XA, 65XA, 69XA,

Continues

Supplementary Table 1. Continued

Category	Category Descriptor	Etiology, Anatomic Site, Severity, Extension
V89	Motor or nonmotor vehicle accident, type of vehicle unspecified	2XXA
V91	Other injury due to accident to watercraft	89XA
V96	Accident to nonpowered aircraft causing injury to the occupant	12XA
W01	Fall on the same level from slipping, tripping, and stumbling	0XXA, 190A, 198A
W03	Other fall on the same level due to collision with another person	XXXA
W05	Fall from a nonmoving wheelchair, nonmotorized scooter, and motorized mobility scooter	0XXA
W06	Fall from a bed	XXXA
W07	Fall from a chair	XXXA
W09	Fall on and from playground equipment	8XXA
W10	Fall on and from stairs and steps	0XXA, 1XXA, 8XXA, 9XXA
W11	Fall on and from a ladder	XXXA
W13	Fall from, out of, or through building or structure	0XXA, 1XXA, 2XXA, 4XXA, 8XXA
W14	Fall from a tree	XXXA
W16	Fall, jump, or diving into water	022A, 522A, 92XA
W17	Other fall from one level to another	4XXA, 89XA
W18	Other slipping, tripping, and stumbling and falls	01XA, 09XA, 11XA, 12XA, 2XXA, 30XA, 39XA
W19	Unspecified fall	XXXA
W20.	Struck by a thrown, projected, or falling object	8XXA,
W21	Striking against or struck by sports equipment	02XA, 03XA, 04XA, 07XA, 89XA
W22	Striking against or struck by other objects	8XXA
W25	Contact with sharp glass	XXXA
W26	Contact with other sharp objects	0XXA, 8XXA
W27	Contact with a nonpowered hand tool	0XXA
W29	Contact with other powered hand tools and household machinery	4XXA
W30	Contact with agricultural machinery	89XA
W31	Contact with other and unspecified machinery	1XXA, 89XA
W32	Accidental handgun discharge and malfunction	0XXA
W34	Accidental discharge and malfunction from other and unspecified firearms and guns	00XA
W37	Explosion and rupture of a pressurized tire, pipe, or hose	8XXA
W39	Discharge of firework	XXXA
W40	Explosion of other materials	8XXA
W50	Accidental hit, strike, kick, twist, bite, or scratch by another person	1XXA
W51	Accidental striking against or bumped into by another person	XXXA
W54	Contact with dog	0XXA
W55	Contact with other mammals	12XA, 22XA
X00	Exposure to uncontrolled fire in building or structure	0XXA, 1XXA
X04	Exposure to ignition of highly flammable material	XXXA
X06	Exposure to ignition or melting of other clothing and apparel	2XXA
X08	Exposure to other specified smoke, fire, and flames	8XXA
X10	Contact with hot drinks, food, fats, and cooking oils	2XXA

Continues

Supplementary Table 1. Continued

Category	Category Descriptor	Etiology, Anatomic Site, Severity, Extension
X12	Contact with other hot fluids	XXXA
X58	Exposure to other specified factors	XXXA
X72	Intentional self-harm by handgun discharge	XXXA
X73	Intentional self-harm by rifle, shotgun, and larger firearm discharge	1XXA
X74	Intentional self-harm by other and unspecified firearm and gun discharge	9XXA
X76	Intentional self-harm by smoke, fire, and flames	XXXA
X80	Intentional self-harm by jumping from a high place	XXXA
X82	Intentional self-harm by crashing of a motor vehicle	8XXA
X83	Intentional self-harm by other specified means	8XXA
X93	Assault by handgun discharge	XXXA
X94	Assault by rifle, shotgun, and larger firearm discharge	0XXA
X95	Assault by other and unspecified firearm and gun discharge	9XXA
X99	Assault by a sharp object	1XXA, 9XXA
Y00	Assault by a blunt object	XXXA
Y03	Assault by crashing of a motor vehicle	0XXA
Y04	Assault by bodily force	0XXA, 2XXA, 8XXA
Y08	Assault by other specified means	02XA, 89XA
Y09	Assault by unspecified means	
Y22	Handgun discharge, undetermined intent	XXXA
Y29	Contact with a blunt object, undetermined intent	XXXA
Y35	Legal intervention	003A, 891A