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Clinical study

Impact of COVID-19 on neurocritical care delivery and outcomes in patients with severe acute brain injury – Assessing the initial response in the first US epicenter

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ABSTRACT

To investigate the pandemic's impact on critically ill patients with neurological emergencies, we compared care metrics and outcomes of patients with severe acute brain injury (SABI) before and during the initial COVID-19 surge at our institution. We included adult patients with SABI during two separate three-month time periods: 'pre-COVID vs COVID'. We further stratified the COVID cohort to characterize outcomes in patients requiring COVID-19 precautions (Patient Under Investigation, 'PUI'). The primary endpoint was in-hospital mortality; secondary endpoints included length of stay (LOS), diagnostic studies performed, time to emergent decompressive craniectomies (DCHC), ventilator management, and end-of-life care. We included 394 patients and found the overall number of admissions for SABI declined by 29 % during COVID (pre-COVID n = 231 vs COVID, n = 163). Our primary outcome of mortality and most secondary outcomes were similar between study periods. There were more frequent extubation attempts (72.1 % vs 76 %) and the mean time to extubation was shorter during COVID (55.5 h vs 38.2 h). The ICU LOS (6.10 days vs 4.69 days) and hospital LOS (15.32 days vs 11.74 days) was shorter during COVID. More PUIs died than non-PUIs (51.7 % vs 11.2 %), but when adjusted for markers of illness severity, this was not significant. We demonstrate the ability to maintain a consistent care delivery for patients with SABI during the pandemic at our institution. PUIs represent a population with higher illness severity at risk for delays in care. Multicenter, longitudinal studies are needed to explore the impact of the pandemic on patients with acute neurological emergencies.

1. Introduction

The coronavirus disease-2019 (COVID-19) pandemic strained intensive care units (ICUs) around the globe, as many patients with COVID-19 require prolonged critical care and mechanical ventilation [1–3]. Early reports from Italy and Spain raised concerns regarding availability of critical care resources [4–6].

In the United States (US), the first case of COVID-19 was reported on January 19th, 2020 near Seattle, Washington (WA) [7]. On February 29,

2020, the first death of a patient with COVID-19 in the US was reported in WA state. Shortly thereafter, Seattle became known as the first epicenter of the pandemic in North America, with increasing reports of COVID-19 cases from long-term care and skilled nursing facilities, and an initial study from nine Seattle-area hospitals reporting 50 % mortality among critically ill patients with COVID-19 [2].

One major concern was that COVID-19 could negatively impact the healthcare system's ability to care for patients with alternative diagnoses [8–10], especially in the face of predicted surges [11].

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Challenges specific to neurocritical care providers included the preservation of capacity and resources to care for neurological emergencies in a timely and effective manner [12–14]. Furthermore, there was concern that safety measures implemented to prevent transmission of COVID-19 might result in critical delays in patient care, specifically for those admitted as “patients under investigation” (PUI) and placed in COVID-19 precautions while requiring frequent neurological examinations, emergent diagnostic studies, and neurosurgical intervention.

The goal of this study was to analyze the impact of the pandemic on the care and outcomes of critically ill patients with severe acute brain injury (SABI) admitted to our Neurocritical Care Service (NCCS). We compared (1) census, care metrics, and outcomes in patients with SABI before and during the first surge of the pandemic, and (2) outcomes for patients with SABI admitted as PUIs and those without a PUI designation. We hypothesized that increased resources devoted to COVID-19 and need for COVID precautions would result in delays in care and reduced diagnostic testing for patients with SABI, potentially leading to an increase in mortality.

2. Methods

2.1. Study setting and patient population

Our institution is an academic county hospital in Seattle that serves as a quaternary referral center for the Pacific Northwest region, a Comprehensive Stroke Center, and the sole Level 1 trauma center in WA state, with a neurocritical care service (NCCS) and a dedicated 30 bed Neurosciences ICU (NICU). The NCCS admits all critically ill patients presenting with acute neurological injuries and co-manages these patients together with the Neurology or Neurosurgery service. As part of the co-management model at our institution, the NCCS team rounds on the patients, makes all major decisions about neurological and neurosurgical care in close communication with the co-managing services, as well as other aspects of the critical care management.

Aside from NCCS, there are three separate critical care services: medical/cardiac ICU, trauma/surgical ICU, and burn/pediatrics ICU. Each service has a designated ICU location and patients are preferentially triaged to the associated ICU location, but the service may manage patients boarding in other ICUs based on bed availability. In our system, all patients with SABI are admitted under NCCS and preferentially assigned a bed in the NICU, or board in other ICU locations but remain under the direct care of the NCCS if there is no bed available in the NICU. Of note, patients with concomitant SABI and COVID were admitted to the NICU/NCCS during the study period.

This was a retrospective cohort study evaluating all adult patients (age > 18 years) admitted to the NCCS during two specified three-month time periods (‘pre-COVID’, ‘COVID’) with a diagnosis of SABI. SABI was defined as acute ischemic stroke (AIS), intracranial hemorrhage (ICH), subarachnoid hemorrhage (SAH), or traumatic brain injury (TBI). Patients admitted to the NCCS with diagnoses other than SABI were excluded, as we sought to determine the pandemic’s impact on the most frequently encountered emergencies in neurocritical care [15]. Our institution is a site for the GCS-NeuroCOVID study (OUTCOMES, <https://clinicaltrials.gov/ct2/show/NCT04496076>). A portion of this data was collected for the consortium. In parallel, we collected multiple additional data points to evaluate process measures relevant to neurocritical care.

The first time period was immediately before the outbreak of the pandemic in the US, between October 1st, 2019–December 31st, 2019 (‘pre-COVID’); the second was shortly after the documentation of the first cases of COVID-19 in Seattle and during the first surge, between March 1st, 2020–May 30th, 2020 (‘COVID’). Patients admitted during the COVID period were further stratified by PUI status on admission. Patients were PUI based on a screening questionnaire (Table S1). When assigned PUI status, patients were isolated in a negative pressure room, and placed in airborne/droplet precautions until cleared with a negative

COVID test (PCR from nasopharyngeal swab, and in high-risk cases, an additional ETT aspirate sample).

Policies enacted during the first COVID-19 surge affecting the NCCS, including precautions taken for patients classified as PUIs, are summarized in Table S2. This study was approved by the University of Washington Institutional Review Board (STUDY ID 00010293).

2.2. Patient characteristics

We collected patient demographic data including age, race, sex, hospital location (‘NICU’ vs ‘Other ICU’), and markers of illness severity, including the proportion of mechanically ventilated patients as well as neurological scores on admission (National Institute of Health Stroke Scale (NIHSS) for AIS, Hunt-Hess score for SAH, ICH score for ICH, and Glasgow Coma Scale (GCS) for all). We additionally included the initial Sequential Organ Failure Assessment (SOFA) score to represent systemic illness severity. We also recorded pre-existing code status limitations – defined as do not resuscitate (DNR) and/or do not intubate (DNI) orders – as potential confounders of outcomes [16,17].

2.3. Outcome measures

Our primary endpoint was in-hospital mortality. Secondary endpoints included ICU and hospital length of stay (LOS), and additional relevant components of care: 1) number of diagnostic studies performed during ICU stay, 2) time to emergent neurosurgical decompressive craniectomies (DCHC), 3) extubation and tracheostomy decisions, and 4) advanced care planning/end-of-life care, as described below. These additional relevant components were collected separate from the GCS-COVID consortium.

Diagnostic studies included computerized tomography (CT) scans of the head (during the entire ICU stay and in the first 24 h, separately), magnetic resonance imaging (MRI) of the brain, transcranial dopplers (TCD), and continuous electroencephalography (EEG). These specific diagnostic studies were selected as these are the most pertinent to the evaluation of patients with SABI. For emergent DCHC, we used the anesthesia record to collect timestamps for case request, patient arrival in the operating room, anesthesia ready, procedure start, and procedure end.

Days on the ventilator were estimated based on each calendar day during which the patient was on mechanical ventilation (MV) during the hospital stay. When assessing the time from first intubation to first extubation attempt, we excluded patients who were terminally extubated as part of a transition to comfort measures. Extubation was considered successful if the patient did not require further MV during their hospital stay. The presence of a tracheostomy was captured by a procedure note, and verified by comments regarding tracheostomy size and management in the nursing and respiratory therapy notes.

Aspects of patient care around advanced care planning included involvement of the palliative care consult service, the date of the initial palliative care consult, and the number of patients with withdrawal of life-sustaining treatment (WLST). The date and time at which the “Comfort Measures Only” order was placed were utilized to calculate the time from admission to CMO transition.

2.4. Analysis

We conducted chi-squared tests on categorical variables and t-tests on continuous variables to evaluate differences in baseline characteristics and key outcomes between 1) the pre-COVID vs COVID study periods and 2) the PUI vs non-PUI cohorts. We performed a multivariate log-binomial regression to examine the impact of COVID as well as effect of PUI status on our primary outcome of mortality to control for potential confounding factors. Potential confounders included age, pre-existing code status limitation, mechanical ventilation, and GCS. Other illness severity scores, such as NIHSS, ICH, or Hunt-Hess Score, were not

used as they only applied to parts of the population. We used a p-value of < 0.05 to indicate statistical significance. Analyses were conducted using R software.

3. Results

3.1. COVID ICU and NCCS census

The daily institutional NCCS census during the COVID period ranged between 6 and 27 patients. Our daily institutional COVID ICU census ranged between 1 and 18 cases. During this period, Washington State experienced its first COVID surge between March–April 2020, which ultimately concluded at a nadir around May 15, 2020. At its peak, there was a 7-day average hospitalization of 74 COVID cases and 7-day average mortality of 27 [18].

3.2. Patient characteristics and census distribution

Overall, 394 patients with SABI (32 % TBI, 31 % ICH, 22 % AIS, 14 % SAH) were hospitalized during both study periods and included in our analysis. Their average age was 61.7 (SD 18.6), 59 % were male, 69 % were Caucasian, the mean GCS was 10.5 (SD 4.84), and 45 % were mechanically ventilated during their ICU stay.

Compared to the pre-COVID period, the overall number of patients admitted to the NCCS with SABI was reduced by 29 % during the COVID study period (pre-COVID n = 231 vs COVID, n = 163). The most notable proportional decline in total admissions was observed for patients with AIS (pre-COVID n = 59 vs COVID n = 29), followed by SAH (n = 33 vs n = 22), ICH (n = 71 vs n = 52), and TBI (n = 67 vs n = 60). Patients with SABI were more frequently boarding in ‘Other ICUs’ rather than the NICU during COVID compared to the pre-COVID period (59 % vs 6 %, p < 0.01).

Most patient characteristics were comparable between pre-COVID and COVID, including age, gender, race, illness severity scores, proportion of patients requiring MV, and with pre-existing code status limitations (Table 1). The proportion of patients with AIS (26 % vs 18 %) was lower during COVID, with similar proportions of patients with ICH (31 % vs 32 %) and SAH (14 % vs 13 %), and higher proportion of patients with TBI (19 % vs 37 %), but these differences were not statistically significant.

During COVID, 29 patients (18 %) with SABI were initially classified

Table 1

Patient characteristics at Harborview Medical Center during pre-COVID period (October–December 2019) and COVID period (March–May 2020).

	Pre-COVID (n = 231)	COVID (n = 163)	p-values
Age (years), mean (sd)	61.2 (18.4)	62.6 (19.0)	0.47
Male sex, n (%)	137/231 (59.3)	96/163 (58.9)	0.93
Race/Ethnicity, n (%)			0.18
Non-Hispanic Caucasian	162 (70.1)	108 (66.3)	
Black/African American	11 (4.8)	17 (10.4)	
Asian	22 (9.5)	12 (7.4)	
Hispanic	22 (9.5)	20 (10.4)	
Other	14 (6.6)	6 (5.5)	
Primary Diagnosis, n (%)			0.27
AIS	59/231 (25.5)	29/163 (17.8)	
ICH	71/231 (30.7)	52/163 (31.9)	
SAH	33/231 (14.3)	22/163 (13.5)	
TBI	67/231 (29.0)	60/163 (36.8)	
PUI, n (%)	N/A	29/163 (17.8)	
Patient located in NICU, n (%)	216/231 (93.5)	67/163 (41.1)	<0.01
GCS, mean (sd)	10.4 (4.8)	10.8 (4.9)	0.35
ICH score, mean (sd)	2.13 (1.36)	1.93 (1.47)	0.42
Hunt-Hess, mean (sd)	2.88 (1.54)	3.00 (1.11)	0.73
NIHSS, mean (sd)	10.1 (12.1)	8.73 (10.9)	0.37
SOFA, median (IQR)	2 (5)	2 (4)	>0.05

as PUIs within 24 h of admission, only one of them was ultimately diagnosed with COVID-19 based on PCR. PUI and non-PUI did not differ significantly in their basic demographics (age, gender, race). Patients in the PUI cohort more often had ICH (41.3 % vs 29.9 %) with similar proportions of AIS (17.2 % vs 17.9 %), SAH (10.3 % vs 14.2 %) and TBI (31.0 % vs 38.1 %) compared to the non-PUI cohort. PUIs had significantly worse illness severity scores, including lower GCS on presentation (7.83 vs 11.5, p < 0.01), higher ICH score (3.25 vs 1.47, p < 0.01), Hunt-Hess (4.33 vs 2.79, p = 0.02), and NIHSS (17.1 vs 6.73, p = 0.01). PUIs also more commonly required MV (72.4 % vs 38.1 %, p < 0.01) and more often had pre-existing code status limitations (62.1 % vs 11.9 %, p < 0.01). There were three PUI and 12 non-PUI who underwent emergent DCHC (p = 0.71).

3.3. Outcomes

All results displaying differences between the pre-COVID and COVID periods, as well as PUI vs non-PUI cohorts, are summarized in Tables 2a and 2b, respectively.

Mortality - In a univariate analysis, we found no differences in our primary endpoint of in-hospital mortality between the pre-COVID and COVID periods (29.0 % vs 18.4 %, p = 0.37). The majority of deaths (preCOVID: 86 %; COVID 90 %) occurred following WLST and transition to CMO. We found higher mortality among the PUI cohort compared to non-PUI in univariate analysis (51.7 % vs 11.2 %, p < 0.01), however this was no longer statistically significant after adjusting for other variables in our multivariate analysis (95 % CI 0.81–4.00, p = 0.15). Instead, the need for MV (95 % CI 1.49–21.72, p = 0.01) and pre-existing limitations on code status (95 % CI 1.65–9.44, p < 0.01) were the strongest predictors of mortality (Table 3).

Table 2a

Outcome measures as described in the methods comparing the pre-COVID and COVID cohorts.

	Pre-COVID (n = 231)	COVID (n = 163)	p-value
In-Hospital Mortality, n (%)	51/231 (22.1)	30/163 (18.4)	0.37
NICU LOS (days), mean (sd)	6.10 (7.0)	4.69 (4.9)	0.02
Hospital LOS (days), mean (sd)	15.3 (17.8)	11.7 (12.7)	0.02
Number of Emergent DCHC, n (%)	24/231 (10.3)	14/163 (8.5)	0.55
Time from Case Request to OR (minutes), mean (sd)	33.8 (26.6)	32.8 (19.2)	0.89
Time from OR arrival to Procedure Start (minutes), mean (sd)	36.4 (15.9)	38.8 (17.9)	0.68
Mechanically Ventilated, n (%)	104/231 (45.0)	72/163 (44.2)	0.87
Estimated Ventilator Days, mean (sd)	4.79 (6.88)	3.87 (4.41)	0.29
Extubation Attempted, n (%)	75/104 (72.1)	55/72 (76.4)	<0.01
Successful Extubation, n (%)	60/75 (80.0)	46/55 (83.6)	0.59
Time to First Extubation Trial (hours), mean (sd)	55.5 (91.9)	38.2 (38.6)	0.15
Tracheostomy, n (%)	5/104 (4.8)	1/72 (1.4)	0.21
Time to Tracheostomy (days), mean (sd)	18.6 (7.60)	11.0 (NA)	**
Transition to CMO, n (%)	44/231 (19.0)	26/163 (16.0)	0.43
Time to CMO Transition (days), mean (sd)	5.66 (8.58)	5.31 (6.50)	0.85
Pre-Existing Code Status Limitations, n (%)	36/231 (15.6)	27/163 (16.6)	0.79
Palliative Care Consulted, n (%)	17/231 (7.4)	9/163 (5.5)	0.47
Time to Consult (days), mean (sd)	8.42 (9.31)	7.81 (6.11)	0.83
Unplanned ICU Readmission, n (%)	7/231 (3.0)	7/163 (4.3)	>0.05
Hospital Readmission, n (%)	29/332 (8.4)	29/257 (11.3)	>0.05

**Due to low number of data points, t-test analysis was unable to be performed on this outcome variable.

Table 2b
Outcome measures during the COVID era stratified by PUI status.

	PUI on admission (n = 29)	Non-PUI (n = 134)	p- value
In-Hospital Mortality, n (%)	15/29 (51.7)	15/134 (11.2)	<0.01
NICU LOS (days), mean (sd)	5.45 (5.75)	4.53 (4.76)	0.43
Hospital LOS (days), mean (sd)	8.83 (6.09)	12.4 (13.7)	0.03
Number of Emergent DCHC, n (%)	3/29 (10.3)	11/134 (8.0)	0.71
Time from Case Request to OR (minutes), mean (sd)	51.3 (30.9)	27.7 (12.6)	0.32
Time from OR arrival to Procedure Start (minutes), mean (sd)	56.7 (19.5)	33.9 (14.7)	0.17
Mechanically Ventilated, n (%)	21/29 (72.4)	51/134 (38.1)	<0.01
Estimated Ventilator Days, mean (sd)	5.10 (5.28)	3.36 (3.93)	0.19
Extubation Attempted, n (%)	13/21 (61.9)	42/51 (82.5)	0.06
Successful Extubation, n (%)	10/13 (76.9)	36/42 (85.7)	0.45
Time to First Extubation Trial (hours), mean (sd)	40.8 (30.8)	37.4 (41.1)	0.75
Tracheostomy, mean (sd)	0	1	0.52
Time to Tracheostomy (days), mean (sd)	–	11	**
Transition to CMO, n (%)	12 (41.3)	14 (10.4)	<0.01
Time to CMO Transition (days), mean (sd)	4.92 (7.19)	5.64 (6.10)	0.79
Pre-Existing Code Status Limitations, n (%)	11/29 (37.9)	16/134 (6.0)	<0.01
Palliative Care Consulted, n (%)	3/29 (10.3)	6/134 (4.5)	0.21
Time to Consult (days), mean (sd)	6.67 (5.03)	8.25 (6.73)	0.69

**Due to no tracheostomies performed on PUI cohort, statistical analysis was unable to be performed.

Table 3
Multivariate analysis evaluating factors associated with in-hospital mortality among the COVID cohort.

	RR (95 % CI)	p-Value
PUI Status	1.81 (0.81–4.00)	0.15
Age	0.98 (0.44–2.20)	0.96
GCS	1.13 (0.35–3.64)	0.84
Pre-Existing Code Status Limitation	4.10 (1.84–9.12)	<0.01
Mechanical Ventilation	6.15 (2.06–18.41)	0.01

Length of Stay – Overall, patients were discharged sooner during COVID compared to pre-COVID, including both ICU (6.10 days pre-COVID vs 4.69 days COVID, $p = 0.02$) and hospital LOS (15.32 days vs 11.74 days; $p = 0.02$ for all patients). Readmission rates after hospital discharge for all hospitalizations were slightly higher during COVID (8.4 % vs 11.2 %), but did not reach statistical significance. For PUIs, ICU LOS was similar to non-PUIs (PUI 5.45 days vs non-PUI 4.52 days) and hospital LOS was shorter (8.83 days vs 12.37 days, $p = 0.03$). The discharge disposition was similar between the two time epochs (, however there was a non-statistically significant trend towards more discharges to home (Table S4). Our unplanned ICU readmission rate was similar between the two periods (3.0 % pre-COVID vs 4.3 % COVID).

Diagnostic Studies – The utilization of diagnostic studies did not significantly differ between the pre-COVID and COVID periods or between PUIs vs non-PUIs (Table S3, $p > 0.05$ for all).

Emergent neurosurgical decompressive craniectomies - DCHC were performed at a similar rate during pre-COVID and COVID (10.3 vs 8.5 %, $p = 0.55$). There was no notable delay (33.8 vs 32.6 min, $p = 0.89$) between the case request for emergent DCHC and patient arriving in the operating room (OR), or OR arrival to procedure start (36.4 vs 38.8 min, $p = 0.68$). However, we did find that patients who were classified as PUI did appear to have longer times from case request to OR arrival (45.8

min [range 17–77] vs 27.7 min [range 10–48], $p = 0.32$) and from OR arrival to procedure start (49.3 min vs 33.9 min, $p = 0.17$), however this difference was not found to be statistically significant. It should be noted that there were only three patients classified as PUI who underwent DCHC.

Ventilator management - The proportion of patients who required MV was similar between pre-COVID and COVID (45 vs 44.2 %, $p = 0.87$), and significantly higher in the PUI cohort compared to non-PUI (72.4 vs 38.1 %, $p < 0.01$). On average, patients remained on the ventilator longer during the pre-COVID period (4.8 days vs 3.8 days) and PUIs remained on the ventilator longer (5.10 vs 3.36 days) compared to non-PUIs; however, these differences were not statistically different. Extubation attempts were more frequent (72.1 vs 76 %, $p < 0.01$) and the percentage of successful extubations was similar between pre-COVID and COVID. The number of tracheostomies was fewer (5 vs 1, $p = 0.21$) and timing to tracheostomy was shorter (18.6 vs 11 days) during COVID.

End-of-life care - The percentage of patients who underwent WLST and transitioned to CMO was similar in the two periods (19 vs 16 %, $p = 0.43$), but significantly higher among PUIs (41.3 vs 10.4 %, $p < 0.01$). The proportion of palliative care consults, time to palliative care consult, and time between admission and CMO transition was similar during pre-COVID vs COVID and between PUI vs non-PUIs.

4. Discussion

In assessing the impact of COVID-19 on critically ill patients with SABI at our institution during the first COVID surge, we found a 30 % reduction in SABI admission and a 50 % reduction in AIS admissions. Contrary to our concerns, most outcomes, including hospital mortality and other key features of patient care in the COVID era, were similar compared to the pre-COVID era. Patients with SABI hospitalized during COVID had shorter ICU and hospital LOS despite similar initial neurological and systemic disease severity. There were more extubation attempts and shorter times to extubation with similar re-intubation rates. Patients classified as PUIs on admission and requiring COVID precautions had higher in-hospital mortality, however this appeared to be due to higher illness severity associated with the PUI designation. In our multivariate analysis, pre-existing code status limitation was the highest predictor of mortality, which aligns with other reports in patients with neurological injury [16,19].

The pandemic's larger scale effect on patients requiring neurocritical care remains insufficiently investigated, with only few studies reporting on patient outcomes [20–22]. Here, we demonstrate the capability of maintaining the same level of care with regards to patient outcomes during the onset of the pandemic at a time of many changes to our system. As the first region affected by COVID-19 in the US, the anticipated surge in March-May 2020 was met with uncertainty and unease at our institution. We were fortunate to not exceed our capacity for critical resources such as ventilators, oxygen supplies and personal protective equipment with our overall ICU bed capacity reaching a maximum of 93 % occupancy during the COVID study period. Rapidly enacted hospital policies and protocols, and public health measures to 'flatten the curve' [23,24] likely minimized severity and impact of our surge. We speculate that this allowed our healthcare system to manage patients with COVID-19 without compromising the care of ICU patients with SABI [25].

The reduced volume of both elective post-operative patients and neurological emergencies (specifically AIS, as well as SAH and ICH) might have created additional flexibility to adapt to the pandemic. While the former reduction was a result of deliberate planning, the latter is not fully explained and concerning. Patients may have been reluctant to present to hospitals for fear of exposure to COVID-19, and social distancing practices may have resulted in under-reporting of symptoms by family members or bystanders. Multiple larger studies similarly found decreased admission rates for AIS at the onset of the pandemic, including diminished emergency stroke alerts and thrombectomy rates

[26,27]. Similarly, a substantial decline in SAH hospitalizations and interventions for ruptured aneurysm has been noted worldwide [28,29]. Reports on the effect of the pandemic on the incidence of TBI vary [30,31], with geographical variations on distancing and traffic-related mandates likely contributing.

A major concerning finding were prolonged times to DCHC among the PUI cohort. While not statistically significant and limited by the small sample size, patients classified as PUI had a nearly 50 % increase in the time to surgical intervention. The impact on outcomes is not clearly established in our cohort, however it has been suggested that surgical intervention after clinical signs of brain herniation may be too late; though optimal timing of DCHC is still controversial and may vary by disease process [32–34]. In patients with SABI, where “time is brain”, more research evaluating the impact of infectious disease precautions on delays in care and outcomes patients are needed. While more widely available and rapid testing now minimizes the need for a PUI designation at our institution, this represents an ongoing challenge for resource-limited settings with lack of testing. Moreover, the care of patients with SABI and asymptomatic COVID infections might be adversely affected by delays.

Our study found shorter ICU and hospital LOS, as well as shorter times to extubation, possibly reflecting increased efforts to expedite discharges in anticipation of COVID surges. Concurrently, we note that there is a slight trend towards more home dispositions among the COVID cohort, however this was not statistically significant. We additionally noted a trend to higher hospital readmission, however this was not specific to the NICU population, but rather to all hospitalizations. There was no systematic change in criteria for determining disposition during this period. One factor that may have played a role may have been patients and families preferring to minimize their stay in the healthcare facilities as much as possible due to limited visitation and fears of contracting COVID-19. It was beyond the scope of this study to determine these factors.

We recognize that this study possesses several limitations. First, our findings describe outcomes from a single center and are not generalizable. We recognize that our hospital system was able to stay within our ICU capacity compared to other centers with more strained capacity, where concerns about marginalization of other populations would more likely be expected to occur [35]. Second, differences in outcomes between subgroups may not be detectable due to our sample size. For example, the proportion of African American patients with SABI was doubled during COVID, however, this was not found to be statistically different, and our study lacked power to examine outcomes based on race; reports consistently show that the pandemic has exacerbated racial disparities [36–38]. Third, mortality is a coarse marker of patient outcome in patients with neurological injury. There may be more subtle differences in functional outcomes that were not captured. Fourth, seasonal variations in incidence of SABI between the pre-COVID and COVID time frames may have impacted admission diagnoses and census data. Fifth, because this study was a retrospective analysis, we can only comment on associations and not causation. Finally, there was variability in protocols and policies regarding PUIs and patients with COVID that may have affected outcomes across the three-month study period. These dynamic changes were a reality of the pandemic at most institutions, and represent challenges experienced by many providers and healthcare systems.

More research exploring the pandemic’s impact on patients with SABI across institutions and over time is needed. Specifically, it will be critical to evaluate the impact on patients with SABI in systems that were most severely strained to help guide discussions on how to preserve care as we face additional surges of the pandemic associated with new variants [39,40].

5. Conclusions

We demonstrate the ability to preserve the level of care for critically

ill patients with neurological emergencies during the pandemic. Our region’s campaign to ‘flatten the curve’, changes enacted swiftly by our institution to preserve ICU capacities, and decreased patient volumes may have contributed to preserving this consistent care. Further research into a pandemic mitigation efforts’ impact on patients with SABI, particularly those who require communicable illness precautions, may provide guiding principles to help prepare our healthcare systems for future crises.

Declaration of Competing Interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jocn.2022.10.009>.

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