Hospital Surge Capacity in Co-Occurring Mass Casualty Incidents

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Hospital Surge Capacity in Co-Occurring Mass Casualty Incidents

By

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A Thesis

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Abstract

The COVID-19 pandemic has brought sweeping disruption and changes across healthcare systems. Examining how these changes have impacted surge capacity and capabilities is necessary to plan for future co-occurring surge-creating events in hospital Emergency Departments (EDs) and Intensive Care Units (ICUs). While there is extensive research on patient surge management, no study has looked at how the presence of a prolonged surge would impact the healthcare system’s ability to handle a concurrent acute patient surge. This study seeks to demonstrate the need for comprehensive planning for co-occurring patient surges in New York State using hospital capacity data from Health and Human Services (HHS) in 18 patient surge-creating events in rural and urban areas. The data was insufficient to show differences in ICU capabilities between treating patients from one incident versus treating patients from two independent patient surges. However, the hospital data showed high levels of hospital overcrowding across the state both during COVID-19 patient surges and during baseline periods.
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Introduction

Hospital emergency departments (EDs) and intensive care units (ICUs) are frequently on the front line of a disaster. During a mass casualty incident (MCI), patient survival relies on hospitals’ ability to manage surges in critical patients occurring simultaneously with an existing patient load (Sheikhbardsiri et al., 2017). Hospitals need to prepare for surge management in order to reduce fatalities (Abir et al., 2012). Hospitals plan for sudden events that increase the patient load quickly and often without warning (Hick et al., 2009). Currently, hospital preparedness planning focuses extensively on managing one surge (Bonnett et al., 2007; Hick et al., 2009; Sheikhbardsiri et al., 2017). However, no research has yet been completed on how a hospital responds to manage a secondary surge.

Compounding disasters are expected to occur more frequently as the impacts of climate change create larger disasters (Field et al., 2012). Risk factors are increasing for severe disasters, such as increased droughts leading to more severe wildfires, which can cause multiple related but separate incidents to occur within short proximity of each other (Field et al., 2012). This pattern can be seen in wildfires, heatwaves, and droughts which have increased both as individual events and as interrelated events since 2010 (AghaKouchak et al., 2020). In multiple, co-occurring, or compounding events, each event individually can cause a patient surge in regional hospitals. During a surge, hospitals are expected to expand their capacity using different techniques to meet the increased need for care in the short term (Hick et al., 2009). Following an MCI, hospitals are still responsible for caring for their patients unrelated to the event (Bonnett et al., 2007) and patients already in the facility may see worse outcomes as medical attention shifts to focus on the critical patients incoming from the MCI (Abir et al., 2012). Therefore, if a hospital is operating close to full capacity throughout an average day, it must have policies and procedures in place to
increase capacity quickly (DeLia, 2006). There is currently no research on whether hospitals can manage an additional surge that occurs after they have already expanded to their crisis surge capacity.

The COVID-19 pandemic caused a massive surge in the United States healthcare system including emergency rooms, ICUs, and beyond (González-Gil et al., 2021). Hospitals have experienced staffing difficulties en masse, many healthcare providers intend to leave the field (Poon et al., 2022) and suffer from high rates of pandemic-related PTSD (Johnson et al., 2020). Other changes to the medical field post-pandemic were less related to the COVID-19 illness itself. These changes include increased use of telehealth appointments in emergency medicine (Stratton, 2021) and more consistent hospital overcrowding (Savioli et al., 2022). Hospitals were forced to increase to surge capacity and persist at that level for extended periods while waves of infected patients hit different areas of the country (Chen et al., 2022). Using the prolonged patient surge caused by the COVID-19 pandemic as the primary surge event, this study assessed how the pandemic surge within hospitals’ EDs and ICUs alters their ability to quickly manage the uptick in patients created by a secondary event such as a natural disaster or mass shooting by assessing total ICU beds available in the weeks preceding, during, and after co-occurring patient surges.

Specifically, this study uses the COVID-19 surge to compare the ICU bed capacity during no surge, a COVID-19 surge, and a secondary MCI surge coinciding with surge-level rates of COVID-19.
Literature Review

Surge capacity is a crucial component of preparedness for hospitals generally and the EDs within them specifically (Sheikhbardsiri et al., 2017). A hospital’s ability to handle a sudden surge of critical patients can be the difference between life or death for the people impacted by a surge-creating event. Overcrowding in hospitals has consequences on the lives of the patients who are coming to the facility to receive critical medical care (Sartini et al., 2022). Better hospital preparedness reduces fatalities and disabilities and improves patient outcomes (Sheikhbardsiri et al., 2017).

Surges and Surge Capacity

Hospital preparedness often revolves around the ability to safely manage general patient surges, however, the techniques used to manage a surge depend on what type of surge a hospital is experiencing. This can change by whether or not there is a warning of the event, the event type, what additional resources are available, and the number of patients (Kaji & Lewis, 2006). There are three main types of surge capacity: conventional, contingency, and crisis surges (Hick et al., 2009). Conventional capacity refers to the maximum resources used in daily operations, while contingency and crisis capacity refers to a level of surge that exceeds normal operations. The largest difference between contingency and crisis capacity is that crisis requires the use of additional physical space, staffing, and supplies that stray from the standard of care (Hick et al., 2009).

It is difficult to plan for a specific surge, and equally difficult to adapt the plans once a surge has started, as the hospitals will often have no context as to when and where their surge in patients will be coming from (Auf der Heide, 2006; Hick et al., 2009; Kaji & Lewis, 2006). Suddenly increasing the number of patients who can be treated in a hospital can be challenging.
Immediately following an MCI, most patients will arrive at an emergency room within 90 minutes of the disaster, before additional resources from outside the area can arrive (Auf der Heide, 2006). In addition, many of the individuals in the initial surge will arrive without warning by personal vehicle or on foot and without necessary decontamination from emergency medical services (EMS) (Kaji & Lewis, 2006). While EMS can communicate with hospitals to distribute patient load more equally, patients arriving without EMS are more likely to go to the facility closest to the MCI site (Auf der Heide, 2006).

There is significant research on how a hospital can expand from daily operations to crisis surge levels. This revolves around the idea that there are four main categories to help facilities extend patient care capacity beyond their everyday capabilities. These are often referred to as the four S’s: Staff, stuff, structure, and systems (Chuang et al., 2021; Sheikhbardsiri et al., 2017). A failure in any of these categories of surge response could result in that facility being unable to reach the needs of its community in the event of an MCI that causes a patient surge (Chuang et al., 2021; Sheikhbardsiri et al., 2017).

United States hospitals during the COVID-19 response surge were found to rely mainly on staff and system surge methods (Post et al., 2023). Once a hospital has employed surge capacity expanding techniques in response to a patient surge, it is unknown if it will be able to adjust its practices further to accommodate a subsequent co-occurring surge.

Staff is the additional patient care and support employees or volunteers available to treat the influx of patients (Hick et al., 2009). Strategies for expanding the staff category include always maintaining staff availability in EDs and ICU(s) regardless of the unit's capacity. This can also include having a structure for crisis on-call staff and providing daycare services for facility staff (Kaji & Lewis, 2006). Staff also includes the knowledge and training of the staff;
training must be done well before an incident occurs (Adini et al., 2006). Staff was found to be one of the greatest challenges in the COVID-19 surge management (Post et al., 2023).

*Stuff* includes tangible resources, specialized or standard (Sheikhbardsiri et al., 2017). This can be limited and challenging to expand in time for the initial wave of people once an event has started (Montán et al., 2022). *Structure* refers to aspects of the physical location (Nekoie-Moghadam et al., 2016). Limitations include maintaining space for critical patients throughout an incident response in the face of an influx of non-critical patients; this can combat crowding caused by least critical patients arriving at the hospital first (Auf der Heide, 2006; Montán et al., 2022). *Systems* include the policy changes during surges that alter the usual standards of patient care; these include plans for reverse triage, early discharge, cancellation of elective surgeries (Kaji & Lewis, 2006), and established agreements to transfer patients to other hospitals that may have more space available (Kelen et al., 2009). These factors are interdependent, and without preparation and readiness in all categories, there cannot be success in reaching crisis surge capacity (Hick et al., 2009). There is also an overlap between sections. For example, a system must be in place to create a daycare for the staff’s children to increase staffing by quickly removing barriers to finding childcare. This would involve both the staff and systems factors.

Surge capacity is essential in determining hospitals’ preparedness levels (Adini et al., 2006; Montán et al., 2022); however, currently, many hospital preparedness models do not include surge capacity measurements (Bonnett et al., 2007; Nekoie-Moghadam et al., 2016). Since surge capacity is a complex calculation, many studies contain a few of the policies and procedures that are involved in increasing surge without using a uniform method to measure full
surge capabilities (Nekoie-Moghadam et al., 2016). Surges and surge capabilities are defined in various ways throughout the literature. The Health Resources and Services Administration (HRSA) takes a regional approach to measuring capacity by assessing the total number of cases per million people within the region that the hospitals should be able to treat. The numbers differ per incident type, including standard trauma, infectious disease, or exposure to chemicals/radiation (Schultz & Koenig, 2006). A facility’s ability to measure surge can be most simply illustrated by the number of patients they can treat per hour assuming approximately one-quarter of the patients require critical care (Bayram et al., 2011).

Engaging the different staff, stuff, and systems techniques to expand patient care capacity to crisis surge levels has challenges. Over the past few decades, the total number of hospital beds in the United States has decreased despite no change in the need for hospital care or even increased need in certain areas (Hick et al., 2004; Sartini et al., 2022). In addition, failures at the community care level, including lack of preventative care and difficulty accessing primary care physicians, lead to more individuals visiting hospital emergency rooms for treatment. This increase combines with the increased complexity of patients, often caused by progressive aging, and an increase in admissions due to seasonal illnesses such as the flu (Sartini et al., 2022). This increases the strain on an already crowded emergency room as they see an increased number of patients with more time and resources required per patient which ultimately shows higher 10-day mortality rates (Richardson, 2006). Constant emergency room overcrowding is also caused by increased return visits or a patient needing to return to the hospital after being discharged too early due to misdiagnosis or other errors. These will often advance further as mistakes become more frequent with increased staff exhaustion and due to growing strain (Sartini et al., 2022). A general shortage of specialized resources such as burn unit space (Chuang et al., 2021),
psychiatric bed space (McBain et al., 2022), decontamination areas and resources (Adini et al., 2006), and even basic surgical resources (Al-Thani et al., 2022) can also impact the ability to expand to surge capacity as the failure of surge capability resources means that there will be more need for general acute care (Auf der Heide, 2006). As these challenges become more prevalent and combine with the increased frequency of co-occurring surges caused by more severe natural disasters (Field et al., 2012), hospitals need to adapt to the changing emergency and critical care needs.

Hospital overcrowding has serious and often deadly implications. One study found that the 10-day mortality rates (the number of deaths occurring within 10 days of individuals arriving at the ED) increased significantly at times when a facility’s ED was overcrowded (Richardson, 2006). However, a different study showed the increase in 30-day mortality rates in septic shock patients was found to be attributed more to the severity of the condition upon arrival than time in the ED before transfer (Elay & Al, 2020). In a 2014 study, the 4-hour mortality rates among all patients presenting to an ED were improved when capacity lowered from 93% to 90% in one United Kingdom hospital (Boden et al., 2016). Collectively, these findings demonstrate the importance of maintaining appropriate capacity during non-surge times for patient outcomes. Patients in facilities prior to the arrival of patients from an MCI often have worse outcomes and longer stays in the facility than they would have if the hospital had not needed to expand its capacity (Abir et al., 2012).

During the COVID-19 pandemic, the most frequently seen hospital capacity-expanding techniques to control overcrowding were: canceling elective surgeries, using field hospitals for overflow, and allowing students or former healthcare workers to work in certain areas of the facility (McCabe et al., 2020). Despite the common use of these tactics, many hospitals did not
deploy any surge plans despite the increased patient load in the facility (McCabe et al., 2020). In an extended event such as a pandemic, canceling elective surgeries can have significant financial and health costs for the individuals whose incidents were canceled. Generally, postponing a necessary but non-urgent surgery leads to increased patient care complexity and worse health (McCabe et al., 2020) however, it has been shown that there is no significant change in post-surgical mortality rates following surgeries with extended wait time (Rexius et al., 2005).

Therefore, for a short-term surge, canceling elective surgeries can clear more space for critical patients following an MCI, however, if the delay in surgery is extended the patient’s condition may worsen (McCabe et al., 2020). This indicates that an MCI surge delay may increase patient complexity, which can increase strain and overcrowding in ERs or ICUs but may not translate into higher mortality rates.

**Co-occurring and Compounding Events**

There are a variety of ways that co-occurring surges may be created. One example is a compound event, a term used in climate science to describe multiple natural disasters that fall into one of the following three categories: (1) Multiple extreme events coinciding, (2) one extreme event that is amplified by underlying conditions in the environment/society, or (3) a combination of multiple events that would not be extreme individually but create an extreme impact when in concert (Field et al., 2012). These have been becoming more frequent and are anticipated to continue to do so (Field et al., 2012). Global increase in heat waves due to greenhouse gasses have coincided with more severe droughts to create more severe wildfires (AghaKouchak et al., 2020) which not only cause deaths from fire, but also an estimated annual 339,000 deaths from smoke inhalation and other debris injuries between 1994-2007 (Johnston et
The number of high-risk days for severe wildfires is anticipated to increase by 70% by 2050 (Yu et al., 2020) likely causing the number of deaths and injuries to increase.

Natural disasters can also cause cascading technological disasters referred to as natechs (Cruz et al., 2004). One example of a natech incident was the 2011 Fukushima Earthquake which triggered a large tsunami, which ultimately led to a nuclear power plant being damaged and nuclear energy being released into the environment (Hasegawa et al., 2016). An ongoing disease outbreak can also create persistent surge-level stress on hospitals. During an event such as COVID-19, which was both a protracted and global event, hospitals were forced to maintain patient levels that were often above their standard capacity (Chen et al., 2022; Savioli et al., 2022). For many facilities, this caused them to initiate their surge plan and continue to operate at that level for months while waves of the virus spread around the country throughout 2020 and 2021 (González-Gil et al., 2021). Additional MCIs during that time were increasing the number of patients in already crowded hospitals while resources were focused on pandemic surges (Sartini et al., 2022). No studies have been completed on how those additional MCIs were managed and the impact that the prolonged surge had on patient outcomes.

Methods

Increased overcrowding in hospitals leading up to the COVID-19 pandemic meant that many hospitals were already struggling to manage their patient loads prior to the start of the pandemic bringing a persistent surge (Sartini et al., 2022). Overcrowding strains the critical ability to suddenly expand capabilities to treat a large flux of patients from an MCI (Hick et al., 2004; Rivara et al., 2006). At the peak of the pandemic, hospitals experienced an increase of 19% in their ICU capacity (Sapiano et al., 2021). Therefore, 19% of facility beds being occupied
by COVID-19 patients was used to represent crisis surge levels within hospitals in this study. With hospitals expanding to reach COVID-19 capacity deploying different surge-expanding techniques normally reserved for MCIs hospitals found themselves managing multiple surges simultaneously (McCabe et al., 2020). *What impact does a long-term medical surge have on hospitals’ ability to handle the patient surge created by a compounding mass casualty incident?*

Persistent hospital overcrowding limits a facility’s ability to expand operations further to meet the needs of an MCI patient surge (Savioli et al., 2022). Additionally, the typical delay in care that is often associated with overcrowded emergency rooms and ICUs can increase the complexity of patient treatment, which can lead a patient to need additional testing and intervention (Abir et al., 2012; Richardson, 2006). During a prolonged surge sustaining overcrowded levels in an ER and ICU, the following are expected:

**H1:** Hospitals will expand the capacity of their ICU less during comparable patient surges with a co-occurring COVID-19 surge as they will see with no co-occurring COVID-19 surge.

**H2:** Hospitals will take longer to return to below ICU surge levels following an MCI during a COVID-19 surge.

In metropolitan areas across the United States, there are an average of 10 trauma centers accessible to individuals within the city (Rivara et al., 2006). The average American is within 60 minutes by helicopter or car/ambulance to 10 trauma centers (Rivara et al., 2006). However, during a surge, the helicopter may become impractical since limited resources such as landing pads and pilots are designated to one patient at a time which takes more time and space than ground ambulances. In practice, less than 1% of incidents that helicopter EMS responds to are considered MCIs (Shekhar et al., 2023). The majority of patients transported from an MCI scene
by EMS will be brought by ambulance (Auf der Heide, 2006). Additional bottlenecks may occur in an individual hospital experiencing a surge in areas such as CT scanning and available ventilators (Bayram et al., 2011). In an urban area, more trauma centers are accessible by ambulance which allows for better distribution of patients between trauma centers and therefore may see less surge on individual facilities.

**H3: Facilities in urban areas will experience a smaller increased surge in ICUs following an MCI during a co-occurring event than rural hospitals.**

**Hospital Capacity Data**

This study used the Department of Health and Human Services (HHS) COVID-19 Reported Patient Impact and Hospital Capacity by Facility data. Data was collected through weekly self-reporting from each facility of the daily patient numbers and bed capacity data values for the preceding 7-day period. Reports must be made from every hospital registered with the Center for Medicare & Medicaid Services (CMS) (with the addition of other voluntary hospitals with reports beginning June 1, 2020). This data excludes psychiatric, rehabilitation, Indian Health Service (IHS), Department of Veterans Affairs (VA), and Defense Health Agency (DHA) facilities. Reports are made to the National Healthcare Safety Network (NHSN) through the HHS TeleTracking system, state, centralized reporting system (organization reporting for multiple facilities), or third-party vendors (COVID-19 Reported Patient Impact and Hospital Capacity by Facility | HealthData.Gov, 2023). According to the training presentation put out in November 2022 to describe changes in reporting location, hospital administrators who are completing the form have the option of using a web form that has fields in plaintext or there is an option to fill information in directly to a .csv file that can be downloaded and filled in Excel which represents each variable by its variable name (Transition Overview and Data Submission...
Facilities, 2022). There is significant missing data in the hospital capacity data as it is self-reported, and compliance with HHS regulations is focused on the submission of the form and not on the contents.

**Mass Casualty Incident Data**

Data for the compounding MCIs was found via open-source references from web-based local news articles. Several events had corresponding police press conferences confirming the number of patients and their distribution between hospitals. For each incident, the date, the number of injuries during the event, and in what region (with counties and zip codes being used for regional identification) the incident occurred was collected from the news sources and used to calculate MCI surge size by facility. This data was used to calculate the independent variables regarding MCI size that are seen in Table 1. These incidents were identified using Google News using the search terms “mass casualty NY” and “multiple injuries NY.” If the destination hospitals for each patient were not available, the nearest appropriate facility was used as the facility experiencing the patient surge. Incidents were excluded in events where there were several area hospitals and patient destinations were unclear.

The following 13 incidents (Table 1) were identified using Google News. These 13 events created 18 patient surges in individual hospitals. Five of the larger MCIs caused surges in two local facilities. For each incident, hospitals’ surge size was measured using news articles and press releases listing the number of patients transported to each facility, or, when that information was not available, the closest hospital(s) were analyzed using the hospital’s county, zip code, and using Google Maps to assess the driving distance from the site of the MCI. If, in an event, the number of patients transported to each hospital was not available, the nearest hospital was used, and the size was estimated to be just over half of the reported patients. Out of these
incidents, the majority were found in urban areas. Events in rural or suburban areas still relied on hospital access in a metropolitan or micropolitan area. Two incidents were co-occurring with weeks when facilities had a reported COVID-19 surge of over 19% of their ICU capacity.

Table 1: Acute Surge MCI Data by Date of Incident

<table>
<thead>
<tr>
<th>Hospital Name</th>
<th>Collection Week</th>
<th>MCI Surge Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIVERSITY HOSPITAL SUNY HEALTH SCIENCE CENTER</td>
<td>8/15/2021</td>
<td>25</td>
</tr>
<tr>
<td>AUBURN COMMUNITY HOSPITAL</td>
<td>8/15/2021</td>
<td>26</td>
</tr>
<tr>
<td>JACOBI MEDICAL CENTER</td>
<td>1/9/2022</td>
<td>19</td>
</tr>
<tr>
<td>ST BARNABAS HOSPITAL</td>
<td>1/9/2022</td>
<td>20</td>
</tr>
<tr>
<td>NYU LANGONE HOSPITALS</td>
<td>4/10/2022</td>
<td>12</td>
</tr>
<tr>
<td>MAIMONIDES MEDICAL CENTER</td>
<td>4/10/2022</td>
<td>12</td>
</tr>
<tr>
<td>ERIE COUNTY MEDICAL CENTER</td>
<td>5/8/2022</td>
<td>10</td>
</tr>
<tr>
<td>GARNET HEALTH MEDICAL CENTER CATSKILLS - (CSK)</td>
<td>11/27/2022</td>
<td>4</td>
</tr>
<tr>
<td>STATEN ISLAND UNIVERSITY HOSPITAL</td>
<td>2/9/2023</td>
<td>24</td>
</tr>
<tr>
<td>GARNET HEALTH MEDICAL CENTER</td>
<td>2/26/2023</td>
<td>6</td>
</tr>
<tr>
<td>WESTCHESTER MEDICAL CENTER</td>
<td>2/26/2023</td>
<td>8</td>
</tr>
<tr>
<td>STRONG MEMORIAL HOSPITAL</td>
<td>3/5/2023</td>
<td>5</td>
</tr>
<tr>
<td>STRONG MEMORIAL HOSPITAL</td>
<td>7/2/2023</td>
<td>3</td>
</tr>
<tr>
<td>NICHOLAS H NOYES MEMORIAL HOSPITAL</td>
<td>8/20/2023</td>
<td>9</td>
</tr>
<tr>
<td>STRONG MEMORIAL HOSPITAL</td>
<td>8/20/2023</td>
<td>3</td>
</tr>
<tr>
<td>WESTCHESTER MEDICAL CENTER</td>
<td>11/5/2023</td>
<td>9</td>
</tr>
<tr>
<td>GLENS FALLS HOSPITAL</td>
<td>1/7/2024</td>
<td>12</td>
</tr>
<tr>
<td>STRONG MEMORIAL HOSPITAL</td>
<td>1/7/2024</td>
<td>4</td>
</tr>
</tbody>
</table>

Measuring surge

According to the Health Resources and Services Administration, hospitals should be able to expand their capacity by 20-25% within the 24 hours following an MCI (Schultz & Koenig, 2006). This benchmark was not evidence-based, and most man-made incidents create approximately a 5% surge (Schultz & Koenig, 2006). During the early months of COVID-19, April and July 2020, ICUs were seeing surges of approximately an additional 19% on their ICUs.
that were already frequently operating at 95% capacity (Post et al., 2023; Sapiano et al., 2021). Therefore, in this study, to identify whether a hospital is experiencing crisis levels of surge using the available data, the total number of patients with COVID-19 in the ICU of a facility must exceed 19% and the total ICU capacity must be at or near capacity in the week prior to the incident occurring.

**Contents of Data and Variable Descriptions**

Context information collected includes the hospital name, the state, county, and zip code the hospital is physically in, and whether the hospital is located in a micropolitan or metropolitan area.

The independent variables used included the date of the report. This data is reported weekly with the date reported representing the first day of the week. Reporting weeks began on Fridays and ended on Thursdays until June 2023 later reports have weeks beginning on Sundays and ending on Saturdays. Another independent variable used is whether the facility is currently experiencing a surge related to COVID-19. Additionally, the total number of beds occupied by COVID-19 patients both within the hospital as a whole and the ICU was measured. This is a binary variable that signifies a surge of over 19% of the facility’s beds being occupied by COVID-19 patients. The presence and size of co-occurring surges were also used as independent variables. This was determined by the presence of an MCI within the hospital’s region during the observation week. Lastly, whether the hospital is located in a statistical metropolitan or micropolitan area or a more rural area was used as an independent variable to examine how hospital concentration may change results.
The dependent variables used are the total number of inpatient hospital beds within a facility (both occupied and vacant), the total number of occupied beds in the facility as well as the total number of beds and total occupied beds within the ICU.

The HHS data is based on weekly sums and averages. Weekly numbers were used to calculate whether a facility was at capacity or expanded to surge. ICU capacity and occupancy were used to compare how quickly hospital ICUs can return to the facility’s baseline capacity the week of and the week(s) following a surge-creating incident both during a COVID-19 surge, and when there is no COVID-19 surge. This was also split between urban and rural areas to see changes in visible surges in environments distinct in their population densities and available services. How many additional patient beds a hospital creates during the week of an incident and the week following was calculated using the total number of hospital beds that are staffed and equipped, whether they are occupied or available. This figure was compared with the following weeks in the same facility to assess if the additional beds added left the facility at full capacity and unable to accept any patients who may come in for unrelated injuries/illnesses.

To adapt the existing HHS data to apply to this project, several dummy variables were created to aid in calculations: (1) COVID-19 surge (confirmed or suspected cases) by dividing total hospitalized COVID-19 patients by total staffed ICU beds. The variable was positive, indicating the facility was experiencing COVID-19 surge, for weeks when this was greater than or equal to 19% as defined by peak COVID-19 surge rates. (2) ICU at capacity was created by calculating weeks that facility ICUs had no available beds by using the daily average of patients over seven days and subtracting the daily average of staffed beds during a period both at the facility and ICU level. This calculation was positive, indicating the hospital had no available beds, for weeks when this figure was greater than or equal to zero. (3) Whole-hospital at capacity
was created by calculating weeks that an entire facility had no beds available by subtracting the seven-day average of adult hospital beds from the total adult patients hospitalized. This variable is positive, indicating that there were no beds available in the facility, for weeks when this figure was greater than or equal to zero.

Analysis

To analyze the first hypothesis, a t-test was proposed to compare the percent of additional beds that hospitals added on average during a patient surge and the average percent of additional beds hospitals added during a patient surge with a co-occurring COVID surge. To analyze the second hypothesis a regression analysis was planned to examine the relationship between the amount of time a hospital spends at crisis capacity before returning to its baseline capacity based on the size of the surge and the existence of an existing COVID surge. The third hypothesis was proposed to be analyzed using a t-test comparing the mean increase in ICU occupancy percent using urban/rural as an independent variable. Due to insufficient data in the required independent variables and inconsistent data in the dependent variables, all three analyses could not be performed as proposed.

Results

Only hospitals within New York State were used since there may be significant variation in hospital operations state-by-state. This is caused by differing hospital regulations by a state’s respective Department of Health (DOH) and other agencies, which often revolves around funding and care costs (Vitaliano & Toren, 1996). Limiting the location also helped manage the search for additional MCIs. Data was first filtered to include only hospitals within New York state leaving 29,551 observations of 166 hospitals over 183 weeks, from August 2nd, 2020, to
January 28th, 2024. During those 183 weeks, 3,042 observations showed a COVID-19 surge of at least 19% of facility beds, 10,106 observations that did not show over 19% COVID-19 patients, and 16,403 missing observations in either one or both of the fields required to calculate the existence of a COVID-19 surge. When using the reporting field that contained hospital numbers of suspected and confirmed COVID-19 or influenza cases 7,002 observations showed a COVID-19 surge of over 19% of patients in the ICU with 6,882 observations that did not meet surge criteria, and 15,667 missing observations. In 6,194 observations facilities had no available ICU beds in the facility, with 20,856 observations which had at least 1 available bed, and 2,501 missing observations. Out of the full facility bed capacity, 32.81% of observations had no available beds across all units in the hospital calculated by a seven-day average with 53.75% having at least one available bed. At the national level, 17.9% of observations calculated had a confirmed COVID-19 surge of 19% capacity or greater with 32% not experiencing a COVID-19 surge and 50.1% missing figures. 36.59% of observations showed that there were no available beds in a facility for a given week with 48.03% having at least one available bed and 15.38% of observations missing one or both figures that went into calculating full capacity measures.

**Hypothesis 1:** *Hospitals will expand the capacity of their ICU less during comparable patient surges with a co-occurring COVID-19 surge as they will see with no co-occurring COVID-19 surge.*

Two hospitals experienced an MCI-related patient surge concurrently with an existing facility COVID-19 patient surge (Table 2). During both surges, the facilities experiencing the COVID-19 surge were not at full ICU capacity with no available beds. Seven hospitals had MCIs that occurred while the hospital was at full capacity with no beds available (Table 3). One hospital had an MCI while the ICU was at capacity, but other hospitals were available in other
units in the facility (Table 3). Since only two hospital observations experienced an MCI during a COVID-19 surge, it was not possible to compare changes in capacity between the levels of events. Therefore, the proposed t-test could not be performed with the existing data.

**Table 2: Mass Casualty Incidents During COVID-19 Surge**

<table>
<thead>
<tr>
<th>Collection week</th>
<th>MCI surge size</th>
<th>Hospital name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/9/2022</td>
<td>19</td>
<td>JACOBI MEDICAL CENTER</td>
</tr>
<tr>
<td>1/9/2022</td>
<td>20</td>
<td>ST BARNABAS HOSPITAL</td>
</tr>
</tbody>
</table>

**Table 3: Hospitals at Full Capacity During Mass Casualty Incident Collection Week**

<table>
<thead>
<tr>
<th>Collection week</th>
<th>MCI surge size</th>
<th>Hospital name</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/10/2022</td>
<td>12</td>
<td>MAIMONIDES MEDICAL CENTER</td>
</tr>
<tr>
<td>5/8/2022</td>
<td>10</td>
<td>ERIE COUNTY MEDICAL CENTER</td>
</tr>
<tr>
<td>11/27/2022</td>
<td>4</td>
<td>GARNET HEALTH MEDICAL CENTER - CATSKILLS - (CSK)</td>
</tr>
<tr>
<td>2/19/2023</td>
<td>6</td>
<td>GARNET HEALTH MEDICAL CENTER</td>
</tr>
<tr>
<td>2/19/2023</td>
<td>8</td>
<td>WESTCHESTER MEDICAL CENTER</td>
</tr>
<tr>
<td>3/5/2023</td>
<td>5</td>
<td>STRONG MEMORIAL HOSPITAL</td>
</tr>
<tr>
<td><strong>12/31/2023</strong></td>
<td>12</td>
<td>GLENS FALLS HOSPITAL</td>
</tr>
</tbody>
</table>

*All hospitals listed in the table had also been at full occupancy the week immediately preceding the selected event.

**Facility was at capacity at ICU-level only

**Table 4: Hospital ICU Bed Capacity for Concurrent COVID-19 and MCI Surges**

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Surge size</th>
<th>Average ICU Capacity</th>
<th>ICU Beds Pre-MCI</th>
<th>ICU Beds MCI</th>
<th>ICU Beds Post-MCI</th>
<th>Average ICU at COVID-19 Surge</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST BARNABAS HOSPITAL</td>
<td>20</td>
<td>291</td>
<td>291</td>
<td>291</td>
<td>291</td>
<td>291</td>
</tr>
<tr>
<td>JACOBI MEDICAL CENTER</td>
<td>19</td>
<td>465</td>
<td>387</td>
<td>387</td>
<td>387</td>
<td>405</td>
</tr>
</tbody>
</table>
For facilities that were at capacity during the observation week an MCI occurred, two facilities showed an increase in ICU bed capacity, and the same two observations saw beds continuing to increase the week following the MCI. Other observations saw no change in ICU bed availability in the observation weeks preceding, during, and after the MCI. Only one observation had ICU capacity above the average capacity during COVID-19 surge periods, which had been sustained at that level for at least one week prior to the incident occurring.

Table 5: Hospital ICU Bed Capacity for Concurrent Full Capacity and MCI Surges

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Surge size</th>
<th>Average ICU Capacity</th>
<th>ICU Beds Pre-MCI</th>
<th>ICU Beds MCI</th>
<th>ICU Beds Post-MCI</th>
<th>Average ICU at COVID-19 Surge</th>
</tr>
</thead>
<tbody>
<tr>
<td>GARNET HEALTH MEDICAL CENTER</td>
<td>6</td>
<td>404</td>
<td>409</td>
<td>409</td>
<td>409</td>
<td>405</td>
</tr>
<tr>
<td>WESTCHESTER COUNTY MEDICAL CENTER</td>
<td>8</td>
<td>715</td>
<td>705</td>
<td>705</td>
<td>705</td>
<td>731</td>
</tr>
<tr>
<td>GLENS FALLS HOSPITAL*</td>
<td>9</td>
<td>156</td>
<td>118</td>
<td>122</td>
<td>146</td>
<td>168</td>
</tr>
<tr>
<td>ERIE COUNTY MEDICAL CENTER</td>
<td>10</td>
<td>552</td>
<td>527</td>
<td>528</td>
<td>535</td>
<td>571</td>
</tr>
<tr>
<td>MAIMONIDES MEDICAL CENTER</td>
<td>5</td>
<td>618</td>
<td>572</td>
<td>572</td>
<td>572</td>
<td>741</td>
</tr>
<tr>
<td>STRONG MEMORIAL HOSPITAL</td>
<td>5</td>
<td>836</td>
<td>741</td>
<td>741</td>
<td>741</td>
<td>946</td>
</tr>
<tr>
<td>GARNET HEALTH MEDICAL CENTER - CATSKILLS</td>
<td>4</td>
<td>86</td>
<td>85</td>
<td>85</td>
<td>85</td>
<td>88</td>
</tr>
</tbody>
</table>

*ICU surge only

Observation weeks for facilities that did not have co-occurring COVID-19 surges and were not at capacity either saw no change in ICU bed capacity or had a decrease in bed capacity. Two facilities exceeded the average capacity of a COVID-19 surge, however, one was already at the higher ICU bed capacity prior to the MCI occurring. The other, Staten Island University
North Hospital, was experiencing a specialized surge of burn victims which relies on the facility’s availability of both ICU and burn unit space, which could not be calculated. It is worth noting that in Auburn Community Hospital, the patient surge was over 20% of the hospital’s ICU capacity, and there was no change in ICU beds due to the 26-patient MCI surge, and Nicholas H Noyes Memorial Hospital which saw a surge of just under 20% of its ICU with no change in ICU capacity.

**Hypothesis two:** *Hospitals will take longer to return to below ICU surge levels following an MCI during a COVID-19 surge.*

When assessing the number of weeks spent at increased surge capacity, it was found that the two hospitals experiencing COVID-19 surges had no change in ICU bed capacity during the week before, during, and after the selected MCI event based on the seven-day average. Both hospitals were at or below the average number of beds in the ICU during all facility COVID-19 surges. Since the average ICU capacity for each facility was not consistent with the pre-MCI capacities (Table 6), it is not possible to determine when a hospital returned to baseline pre-MCI capacity. The proposed t-test could not be run without a consistent baseline on which to test the change in weeks to baseline.
### Table 6: Hospital ICU Bed Capacity for MCI Surge Without Concurrent Surge

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Surge size</th>
<th>Average ICU Capacity</th>
<th>ICU Beds Pre-MCI</th>
<th>ICU Beds MCI</th>
<th>ICU Beds Post-MCI</th>
<th>Average ICU at COVID-19 Surge</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUBURN COMMUNITY HOSPITAL</td>
<td>26</td>
<td>103</td>
<td>105</td>
<td>105</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>UPSTATE UNIVERSITY HOSPITAL</td>
<td>25</td>
<td>548</td>
<td>597</td>
<td>597</td>
<td>597</td>
<td>554.77</td>
</tr>
<tr>
<td>STRONG MEMORIAL HOSPITAL (3 identical observations)</td>
<td>4, 3, 3</td>
<td>836</td>
<td>741</td>
<td>741</td>
<td>741</td>
<td>946</td>
</tr>
<tr>
<td>WESTCHESTER COUNTY MEDICAL CENTER</td>
<td>9</td>
<td>715</td>
<td>705</td>
<td>705</td>
<td>705</td>
<td>731</td>
</tr>
<tr>
<td>NYU LANGONE</td>
<td>13</td>
<td>1660</td>
<td>1581</td>
<td>1565</td>
<td>1580</td>
<td>1583</td>
</tr>
<tr>
<td>NICHOLAS H NOYES MEMORIAL HOSPITAL</td>
<td>9</td>
<td>44</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>STATEN ISLAND UNIVERSITY NORTH HOSPITAL</td>
<td>24</td>
<td>629</td>
<td>683</td>
<td>665</td>
<td>629</td>
<td>643</td>
</tr>
</tbody>
</table>

**Hypothesis Three:** *Facilities in urban areas will experience a smaller increased surge in ICUs following an MCI during a co-occurring event than rural hospitals.*

There was not enough data on events in rural areas to analyze hypothesis three, that facilities in urban areas will experience a smaller increased surge in ICUs following an MCI during a co-occurring event than rural hospitals. Of the events analyzed, only one event caused a surge in a hospital that was not located in a metropolitan or micropolitan statistical area, despite several incidents occurring in suburban or rural areas. Many rural events were large motor vehicle accidents located on highways, which provides quick access to metropolitan areas and hospitals. In small to medium surges it is possible to quickly airlift critical patients to the nearest
trauma center and provide rapid ground transportation to the nearest appropriate facility (Rivara et al., 2006). With only one event causing a surge in a hospital in a rural area, and insufficient data on the potential bed increase average between urban area hospitals, the proposed t-test could not be completed.

Discussion

While it is not possible to determine the impact specifically of COVID-19 surges on a hospital’s abilities to handle an acute patient surge, the importance of hospital overcrowding from any ongoing patient surge can be demonstrated in the length that hospitals remain at capacity following an MCI. In the events studied, few hospitals increased their ICU capacity during a surge despite the facility being at its full capacity. These observations, while not enough to support the hypothesis, show that the weeks following an incident may show an increased need for ICU space. This would need to be examined further in future work to identify the causes of the increased need for ICU space. This could be caused solely by the increased number of critical patients who need to be admitted into intensive care. Alternatively, increased demand for ICU space may be a result of the combination of MCI patients and community patients causing increased hospital overcrowding, leading to worse outcomes for both MCI-related patients and community patients being treated in the facilities at the same time (Boden et al., 2016; Sartini et al., 2022; Upton et al., 2021). A case study approach would be particularly well suited to this as it would give insight into what techniques hospitals are taking to meet the increased capacity needs of concurrent events as well as detailing patient outcomes from the different groups.

There is still much that is left unknown regarding the organizational behavior of hospitals during prolonged overcrowding and MCIs. Events that force hospitals to start taking steps to
increase their surge capability would likely have shown in the data through above-average ICU, ED, and all inpatient bed capacity. However, other factors could be in play, for example, during COVID-19 surges, hospitals may have experienced increased rates of infection among staff which would render useless any attempts to increase staff from a facility pool to treat an influx in patients (Arabi et al., 2021; McCabe et al., 2020).

The results of this study showed that not all hospitals increased the number of ICU beds despite the ICU already being at full capacity when an MCI occurred. It is difficult to determine why a facility would not increase the number of available ICU beds by employing crisis surge protocols. This may be explained by hospitals’ use of reverse triage. Reverse triage is the process of discharging patients with the least need to make room for patients with higher need (De Bondt et al., 2022). This could be done by discharging patients in the emergency room to follow up with their primary care doctors, removing an individual from an ICU who may under normal circumstances stay for further observation, or transferring low-risk patients to a nursing facility or different hospital (De Bondt et al., 2022). A decrease in bed capacity in MCIs when hospitals were not at capacity or co-occurring COVID-19 surge could also be caused by previously staffed beds being closed to improve the staff-to-patient ratios for the critical patients who arrived at the facility from the MCI. This would be unclear without more information on the community situation surrounding the facility.

Limitations and Future Research

The limited number of MCIs, especially during times of COVID-19 surges within New York State were limited, therefore the hypotheses could not be tested as proposed. Lack of ED admission data requires assumptions on the exact number of critical patients arriving per hospital
as well as whether the surges could be created by other factors in the community, especially
within urban areas. Additionally, data aggregated by weekly averages and sums makes the
impact of smaller surges more difficult to identify. In a future study, different measures may
need to be applied to determine when hospitals have returned to their baseline capacity. The
HHS data set had significant missing data both nationally and in New York State, which also
limited possible results.

As large co-occurring surges are rare events, a qualitative analysis of how individual
hospital(s) handled co-occurring surges during the COVID-19 pandemic, or otherwise, would
provide valuable insights. Another potential study is a time-series analysis looking at one facility
over several years and analyzing the events that caused changes in capacity. These may be able
to assist in actionable procedure goals that can be implemented by facilities to be better prepared
for concurrent patient surge management moving forward. These studies could be coupled with a
review of documentation and plans for adaptability to co-occurring events.

Conclusion

None of the proposed hypotheses could be analyzed due to the lack of large-scale MCI
that occurred during peak COVID-19 periods. Descriptive statistics from the data collected by
the HHS did show the following: (1) Facilities had no available ICU beds in approximately 30%
of observations. (2) During co-occurring overcrowding or COVID-19 and MCI patient surges
there was no identifiable pattern of ICU bed capacity increase or decrease. (3) During MCI
patient surges with no co-occurring surge, the number of available ICU beds either decreased or
had no change. Ultimately, there were not enough observations to determine if this is related to
the existence of an MCI or if it is related to other factors in the community surrounding the
hospital during the observation week.
There is not sufficient evidence to suggest that in any of the selected MCIs, any of the traditional surge-capacity-increasing steps described earlier were taken. Further research is necessary to better understand how hospitals that experienced true co-occurring crisis-level surges managed their patient intake after the initial surge protocols had been put in place.
References


https://doi.org/10.1186/s12960-022-00764-7


https://doi.org/10.1089/hs.2023.0019


https://doi.org/10.3390/healthcare10091625


## Appendix - Variable Names and Data Types

### Demographic information

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<thead>
<tr>
<th>Variable</th>
<th>Variable name</th>
<th>Variable type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital name</td>
<td>Hospital_name</td>
<td>String</td>
</tr>
<tr>
<td>State</td>
<td>State</td>
<td>String</td>
</tr>
<tr>
<td>Metropolitan/micropolitan</td>
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### Independent variables

<table>
<thead>
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<th>Variable name</th>
<th>Variable type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>Collection_week</td>
<td>Date</td>
</tr>
<tr>
<td>COVID-19 surge (confirmed)</td>
<td>Total_adult_patients_hospitalized_confirmed_covid(v31) / Total_staffed_icu_beds &gt;= .19</td>
<td>Y/N</td>
</tr>
<tr>
<td>COVID-19 surge (confirmed &amp; suspected)</td>
<td>Total_adult_patients_hospitalized_confirmed_and_suspected_covid / Total_staffed_icu_beds &gt;= .19</td>
<td>Y/N</td>
</tr>
<tr>
<td>At capacity (ICU)</td>
<td>staffed_adult_icu_bed_occupancy_ - total_icu_beds_7_day_avg &gt;=0</td>
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<tr>
<td>At capacity (whole hospital)</td>
<td>total_adult_patients_hospitalize - all_adult_hospital_beds_7_day_av &gt; 0</td>
<td>Y/N</td>
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Independent variables from outside sources

<table>
<thead>
<tr>
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<th>Variable type</th>
<th>Source/calculation</th>
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<td>MCI surge</td>
<td>MCI_surge</td>
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<td>Open-source news articles</td>
</tr>
<tr>
<td>MCI surge size</td>
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<td>Open-source news articles</td>
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</table>

Dependent variables

<table>
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<th>Variable type</th>
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<td>All hospital inpatient bed occupancy</td>
<td>Staffed_icu_bed_occupancy</td>
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</tr>
<tr>
<td>ICU beds</td>
<td>Total_staffed_icu_beds</td>
<td>Numeric</td>
</tr>
<tr>
<td>ICU bed occupancy</td>
<td>Staffed_icu_bed_occupancy</td>
<td>Numeric</td>
</tr>
<tr>
<td>Total hospitalized adult suspected or laboratory confirmed COVID-19 patients</td>
<td>Total_adult_patients_hospitalized_confirmed_and_suspected_covid</td>
<td>Numeric</td>
</tr>
<tr>
<td>Weeks spent at crisis surge capacity</td>
<td>Time_to_recovery</td>
<td>numeric</td>
</tr>
<tr>
<td>Total hospitalized adult suspected or laboratory confirmed COVID-19 patients</td>
<td>Total_adult_patients_hospitalized_confirmed_and_suspected_covid</td>
<td>Numeric</td>
</tr>
</tbody>
</table>