BRIEF REPORT

OPEN

Frequency and Trends of Pre-Pandemic Surge Periods in U.S. Emergency Departments, 2006–2019

George L. Anesi, MD, MSCE, MBE[1]
Ruiying (Aria) Xiong, MS[2]
M. Kit Delgado, MD, MS[2,3]

OBJECTIVES: To quantify the frequency, outside of the pandemic setting, with which individual healthcare facilities faced surge periods due to severe increases in demand for emergency department (ED) care.

DESIGN: Retrospective cohort study.

SETTING: U.S. EDs.

PATIENTS: All ED encounters in the all-payer, nationally representative Nationwide Emergency Department Sample from the Healthcare Cost and Utilization Project, 2006–2019.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Frequency of surge periods defined as ED months in which an individual facility ED saw a greater than 50% increase in ED visits per month above facility-/calendar month-specific medians. During 2006–2019, 3,317 U.S. EDs reported 354,534,229 ED visits across 142,035 ED months. Fifty-seven thousand four hundred ninety-five ED months (40.5%) during the study period had a 0% to 50% increase in ED visits that month above facility-specific medians and 1,952 ED months (1.4%) qualified as surge periods and had a greater than 50% increase in ED visits that month above facility-specific medians. These surge months were experienced by 397 unique facility EDs (12.0%). Compared with 2006, the most proximal pre-pandemic period of 2016–2019 had a notably elevated likelihood of ED-month surge periods (odds ratios [ORs], 2.36–2.84; all $p < 0.0005$). Compared with the calendar month of January, the winter ED months in December through March have similar likelihood of an ED-month qualifying as a surge period (ORs, 0.84–1.03; all $p > 0.05$), while the nonwinter ED months in April through November have a lower likelihood of an ED-month qualifying as a surge period (ORs, 0.65–0.81; all $p < 0.05$).

CONCLUSIONS: Understanding the frequency of surges in demand for ED care–which appear to have increased in frequency even before the COVID-19 pandemic and are concentrated in winter months–is necessary to better understand the burden of potential and realized acute surge events and to inform cost-effectiveness preparedness strategies.

KEY WORDS: capacity strain; disaster; emergency departments; preparedness; surge event

The global community has shared in experiencing multiple surge events during the COVID-19 pandemic (1). Surge events are the extreme end of a spectrum of healthcare capacity strain, the operations concept of approaching or exceeding of limits placed on a care team, hospital, or health system's ability to provide high-quality care for all patients who may need it at a given time. Capacity strain in general and surge events in particular can be

DOI: 10.1097/CCE.0000000000000954

KEY POINTS

Question: What are the frequency and trends of pre-pandemic surge periods in U.S. emergency departments (EDs)?

Findings: During 2006–2019, 1.4% of U.S. ED months qualified as surge periods and had a greater than 50% increase in ED visits that month above facility- and calendar month-specific medians. These surge months occurred in 12.0% of EDs nationally. Surge periods were concentrated in winter and appeared to increase during the immediately pre-pandemic years.

Meanings: While rare, severe increases in demand for acute care do occur outside of a pandemic setting. Understanding the frequency of surges is necessary to inform cost-effectiveness preparedness strategies.

triggered by numerous patient and system factors such as increased patient volume, acuity, and turnover, and interrupted resource availability. Surge events can be further conceptually distinguished from high but routine variations in strain based on: severe increases in demand for care; deviations from normal care delivery due to space, staff, and supply constraints; and, most severely, the breakdown of standard of care (2).

Truly catastrophic large-scale surge events are rare. Less severe but still-impactful acute and subacute surge periods, however, occur or may occur due to a wider range of both infrequent and more common etiologies including: respiratory viral waves and other local disease outbreaks; (3) extremes of weather (e.g., hurricanes, floods, and wildfires) with associated acute injuries, exacerbations of chronic conditions, and concomitant resource and infrastructure loss (4, 5); and mass trauma including from attacks on the public (e.g., mass shootings) (6). Random or multifactorial variation can also contribute to periods of capacity strain and surge (7, 8).

Emergency departments (EDs), as frontline providers and the source for most hospital admissions, may be the first to experience increases in demand for acute care and are particularly vulnerable to subsequent adverse impacts on care delivery and outcomes. Increases in ED volume can lead to delays in care and interrupted access to care, all of which are associated with poorer patient outcomes (9–18). We therefore sought to quantify the frequency, outside of the pandemic setting, with which individual healthcare facilities nationally are faced with surge periods due to all-cause severe increases in demand for ED care.

METHODS

We performed a retrospective cohort study of publically available pre-pandemic U.S. ED data from 2006 to 2019 from the all-payer, nationally representative Nationwide Emergency Department Sample (NEDS) from the Healthcare Cost and Utilization Project (HCUP), a federal-state-industry partnership sponsored by the Agency for Healthcare Research and Quality (19, 20). The time unit of analysis was at the level of the ED-month (i.e., facility-month), as HCUP excludes individually identifying encounter-level data including visit dates, precluding calculation at more granular time intervals (i.e., ED-week or ED-day). We excluded NEDS EDs records with missing date information (14.5%).

To account for facility-level historical norms and seasonal variation, we standardized the volume of ED visits for each ED-month to the median volume of ED visits for that facility and calendar month across years in the study period (i.e., standardizing January 2006 ED visits at one facility to ED visits during January 2006–2019 at the same facility). We defined surge periods a priori as ED months in which an individual facility ED saw a greater than 50% increase in ED visits per month above the facility-/calendar month-specific medians. As an example, a facility at the sample median with 1,771 ED visits per month (a mean of 59 ED visits per day), would qualify as having a surge month if it experienced 2,657 or more ED visits in a given month (or at least a mean of 89, or 30 additional, ED visits per day in a given month).

We used logistic regression to model the likelihood of a given ED-month being classified as a surge period based on calendar year (2006–2019) and calendar month. We intentionally did not adjust for changes in ED visits per capita over time as they have been relatively consistent during the study period (21) and calendar year was an exposure of interest. We report odds ratios (ORs) and predicted probabilities of an ED-month qualifying as a surge period with 95% CIs. Due to the risk of smaller or lower volume EDs producing artificially high percent increases from

facility-specific medians, we performed sensitivity analyses stratified by quartile of ED visit volume.

p values of less than 0.05 were considered statistically significant. Analyses were conducted using Stata (StataCorp, College Station, TX). Review by an institutional review board is not necessary for the use of publically available HCUP limited datasets which do not qualify as human subjects research; all authors executed and adhered to the requirements of the HCUP Data Use Agreement for Nationwide Databases which is consistent with HIPAA requirements for use of a limited dataset (19).

RESULTS

During 2006–2019, 3,317 U.S. EDs reported 354,534,229 ED visits across 142,035 ED months in NEDS (**Table S1**, http://links.lww.com/CCX/B234). After standardizing to facility and calendar month historical data across all study years, 57,495 ED months (40.5%) during the study period had a 0% to 50% increase in ED visits that month above facility-specific medians and 1,952 ED months (1.4%) qualified as surge periods and had a greater than 50% increase in ED visits that month above facility-specific medians (1,403 [1.0%] and 872 [0.6%] when restricted to EDs with ≥ 10 and ≥ 50 median ED visits per day, respectively). These surge months were experienced by 397 unique facility EDs (12.0%). The historical pre-pandemic likelihood that any given U.S. facility ED would experience a surge month in a given year was 0.9%.

Figure 1 and **Table S2** (http://links.lww.com/CCX/B234) report the relationship between study year and the likelihood of an ED-month qualifying as a surge period, standardized to facility and calendar month. Compared with 2006, the years 2007 and 2015–2019 had higher odds of an ED-month qualifying as a surge period, with the most proximal pre-pandemic period of 2016–2019 with a notably elevated likelihood of ED-month surge periods (ORs, 2.36–2.84; all $p < 0.0005$). During 2016–2019, the range of annual predicted probabilities of an ED-month qualifying as a surge period was 2.25–2.70% compared with a range of 0.52–1.59% for the 2006–2015 periods. In the stratified analysis (**Fig. S1**, http://links.lww.com/CCX/B234), this pattern was most pronounced in the highest ED visit volume quartile.

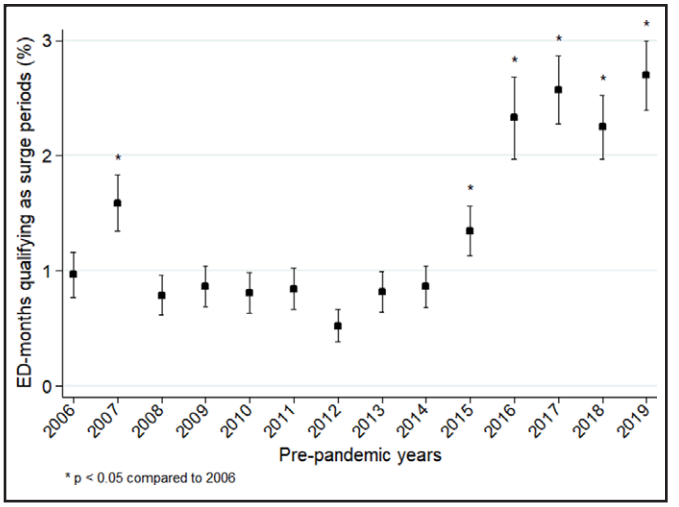

Figure 1. Predicted proportion of emergency department (ED) months meeting surge criteria by year. The volume of ED visits for each ED-month was standardized to the median volume of ED visits by facility and calendar month across years in the study period. Surge periods were defined as ED months in which an individual facility ED saw a greater than 50% increase in ED visits per month above the facility-/calendar month-specific medians. Compared with 2006, the years 2007 and 2015–2019 had higher odds of an ED-month qualifying as a surge period. During 2016–2019, the range of annual predicted probabilities of an ED-month qualifying as a surge period was 2.25–2.70% compared with a range of 0.52–1.59% for the 2006–2015 period.

Figure 2 and **Table S3** (http://links.lww.com/CCX/B234) report the relationship between calendar month and the likelihood of an ED-month qualifying as a surge period after the same standardization approach. Compared with the calendar month of January, the winter ED months in December through March have similar likelihood of an ED-month qualifying as a surge period (ORs, 0.84–1.03; all $p > 0.05$), while the nonwinter ED months in April through November have a lower likelihood of an ED-month qualifying as a surge period (ORs, 0.65–0.81; all $p < 0.05$), all standardized against like calendar months (i.e., one January relative to all other Januaries) across the study period. During December–March ED months, the range of monthly predicted probabilities of an ED-month qualifying as a surge period was 1.45–1.76% compared with a range of 1.11–1.40% for the April–November ED months. In the stratified analysis (**Fig. S2**, http://links.lww.com/CCX/B234), this pattern persisted across all ED visit volume quartiles.

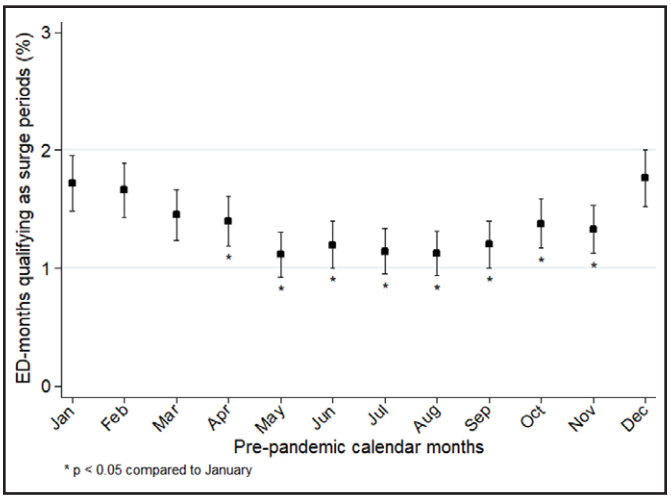

Figure 2. Predicted proportion of emergency department (ED) months meeting surge criteria by calendar month. The volume of ED visits for each ED-month was standardized to the median volume of ED visits by facility and calendar month across years in the study period. Surge periods were defined as ED months in which an individual facility ED saw a greater than 50% increase in ED visits per month above the facility-/calendar month-specific medians. Compared with the calendar month of January, the winter ED months in December through March had similar likelihood of an ED-month qualifying as a surge period (odds ratios [ORs], 0.84–1.03; all $p > 0.05$), while the nonwinter ED months in April through November had a lower likelihood of an ED-month qualifying as a surge period (ORs, 0.65–0.81; all $p < 0.05$), all standardized against like calendar months (i.e., one January relative to all other Januaries) across the study period.

DISCUSSION

This descriptive study of over 350 million ED visits from over 3,300 nationally representative U.S. EDs across 14 years demonstrates that, while rare, severe increases in demand for acute care, in the form of ED visits relative to facility and seasonal historical norms, do occur outside of a pandemic setting. Specifically, during this 14-year pre-pandemic study period, over one in 10 U.S. EDs in a nationally representative sample experienced at least one surge period defined as a calendar month in which the ED saw a greater than 50% increase in ED visits per month above the facility-/calendar month-specific medians. These surge periods appeared concentrated in winter months—namely, winter deviations from winter historical norms were more common than nonwinter deviations from nonwinter historical norms—and appeared to increase during the immediately pre-pandemic years of the study period especially among high-volume EDs.

With ED visits per capita largely stable nationally over time during the study period (21), explanations for the increased frequency of surge periods during the immediately pre-pandemic years must be due to phenomena other than a recent increase in total ED utilization. While total U.S. ED utilization has not significantly changed, where patients seek emergency care and for what those patients are at risk may have shifted. For example, high-impact weather and climate disaster events have increased in frequency during the latter part of the study period, continuing to the present day (5). Such events create primary injuries and illnesses requiring acute care evaluation but they can also threaten health maintenance for many more regional residents with chronic illness that then require care escalation (i.e., due to interrupted access to medications, home care, and outpatient visits) (22). Shunting of usual acute care volume between facilities or regions may occur acutely due to damaged healthcare infrastructure during aforementioned climate disasters or more longitudinally due to financial pressures and closures of hospitals and EDs (23, 24). Further research is needed to better understand what accounts for the increasing frequency of surge periods to inform preparedness and response efforts.

Preparedness for rare surge events is challenging. Attention from leadership and funders amplified during a public health emergency may wane quickly after an acute event resolves. Preparedness infrastructure not used between rare events can quickly atrophy—physically in the setting of tangible equipment and supplies, and organizationally when champions and stakeholders change positions and processes are not tested (25). Documenting that surge periods, while rare, do occur and that a nontrivial proportion of U.S. facilities will experience one at some point, may help support efforts to overcome these barriers to preparedness. The ultimate goal is a local, regional, and national preparedness infrastructure that is: financially and operationally sustainable; built prior to public health emergencies so that capacity building occurs before said capacity is acutely needed; and at least partially integrated into between-emergency normal uses to help justify and sustain longitudinal funding and maintain working order.

This study has important limitations. First, capacity strain and acute surge episodes are complex phenomena due to the interaction of many patient and

systems factors; this study looked at only a single contributor to strain—ED visit volume relative to facility and seasonal historical norms. Second, the data used for this study does not included changes in ED bed capacity during the study period or other secular trends in U.S. ED utilization. Finally, due to HCUP data granularity limited to calendar month, our analysis was on the level of the ED-month and would miss shorter duration acute surge periods, which are likely more common than month-long periods of surge.

CONCLUSIONS

Understanding the frequency of surges in demand for ED care—which appear to have increased in frequency even before the COVID-19 pandemic and are concentrated in winter months—is necessary to better understand the burden of acute surge events and to inform cost-effectiveness preparedness strategies. Increased granularity of national hospital surveillance data, with proper patient privacy protections, would improve the precision of surge science and preparedness.

1 *Division of Pulmonary, Allergy, and Critical Care, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA.*

2 *Penn Medicine Center for Health Care Innovation, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA.*

3 *Center for Emergency Care Policy and Research, Department of Emergency Medicine, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA.*

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/ccejournal).

Dr. Anesi is supported by National Institutes of Health K23HL161353 and University of Pennsylvania Perelman School of Medicine Thomas B. McCabe and Jeannette E. Laws McCabe Fund, he reports payments for authoring chapters for UpToDate and for expert witness consulting, he reports that his spouse is employed by the U.S. Food and Drug Administration, and he is a member of the Editorial Board of Critical Care Explorations. Dr. Delgado reports support from a philanthropic donation from the Abramson Family Foundation. Dr. Xiong has disclosed that she does not have any potential conflicts of interest.

For information regarding this article, E-mail: george.anesi@pennmedicine.upenn.edu

REFERENCES

1. Mathieu E, Ritchie H, Rodés-Guirao L, et al: Our World in Data: Coronavirus Pandemic (COVID-19), 2020. Available at: https://ourworldindata.org/coronavirus. Accessed April 14, 2023
2. Anesi GL, Lynch Y, Evans L: A conceptual and adaptable approach to hospital preparedness for acute surge events due to emerging infectious diseases. *Crit Care Explor* 2020; 2:e0110
3. Furlow B: Triple-demic overwhelms paediatric units in US hospitals. *Lancet Child Adolesc Health* 2023; 7:86
4. Burke M, Driscoll A, Heft-Neal S, et al: The changing risk and burden of wildfire in the United States. *Proc Natl Acad Sci U S A* 2021; 118:e2011048118
5. National Centers for Environmental Information: U.S. Billion-Dollar Weather and Climate Disasters. 2023. Available at: https://www.ncei.noaa.gov/access/billions. Accessed July 3, 2023
6. Myers SR, DeSimone JD, Lorch SA, et al: US hospital type and proximity to mass shooting events. *JAMA Surg* 2020; 155:446–447
7. Anesi GL, Chowdhury M, Small DS, et al: Association of a novel index of hospital capacity strain with admission to intensive care units. *Ann Am Thorac Soc* 2020; 17:1440–1447
8. Anesi GL, Liu VX, Gabler NB, et al: Associations of intensive care unit capacity strain with disposition and outcomes of patients with sepsis presenting to the emergency department. *Ann Am Thorac Soc* 2018; 15:1328–1335
9. Al-Qahtani S, Alsultan A, Haddad S, et al: The association of duration of boarding in the emergency room and the outcome of patients admitted to the intensive care unit. *BMC Emerg Med* 2017; 17:34
10. Andrew Taylor R, Venkatesh A, Parwani V, et al: Applying advanced analytics to guide emergency department operational decisions: A proof-of-concept study examining the effects of boarding. *Am J Emerg Med* 2018; 36:1534–1539
11. DeLaney M: Emergency department boarding: The canary in the coal mine. *J Am Coll Emerg Physicians Open* 2021; 2:e12290
12. Falvo T, Grove L, Stachura R, et al: The opportunity loss of boarding admitted patients in the emergency department. *Acad Emerg Med* 2007; 14:332–337
13. Janke AT, Melnick ER, Venkatesh AK: Monthly rates of patients who left before accessing care in US emergency departments, 2017-2021. *JAMA Netw Open* 2022; 5:e2233708
14. Kilaru AS, Scheulen JJ, Harbertson CA, et al: Boarding in US academic emergency departments during the COVID-19 pandemic. *Ann Emerg Med* 2023 Jan 19. [online ahead of print]. doi:10.1016/j.annemergmed.2022.12.004
15. Reznek MA, Upatising B, Kennedy SJ, et al: Mortality associated with emergency department boarding exposure: Are there differences between patients admitted to ICU and non-ICU settings? *Med Care* 2018; 56:436–440
16. Schreyer KE, Martin R: The economics of an admissions holding unit. *West J Emerg Med* 2017; 18:553–558
17. Singer AJ, Thode HC Jr, Viccellio P, et al: The association between length of emergency department boarding and mortality. *Acad Emerg Med* 2011; 18:1324–1329
18. Viccellio P, Zito JA, Sayage V, et al: Patients overwhelmingly prefer inpatient boarding to emergency department boarding. *J Emerg Med* 2013; 45:942–946

19. HCUP Nationwide Emergency Department Sample (NEDS): Healthcare Cost and Utilization Project (HCUP), 2006–2017. Rockville, MD, Agency for Healthcare Research and Quality. Available at: www.hcup-us.ahrq.gov/nedsoverview.jsp. Accessed August 4, 2023
20. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP) Data Partners. Available at: https://hcup-us.ahrq.gov/db/hcupdatapartners.jsp. Accessed March 6, 2023
21. Office of the Assistant Secretary for Planning and Evaluation, U.S. Department of Health & Human Services: Trends in the Utilization of Emergency Department Services, 2009-2018. 2021. Available at: https://aspe.hhs.gov/pdf-report/utilization-emergency-department-services. Accessed July 3, 2023
22. Suneja A, Chandler T, Schlegelmilch J, et al: Chronic Disease After Natural Disasters: Public Health, Policy, and Provider Perspectives. New York, NY, National Center for Disaster Preparedness, Columbia University Earth Institute, 2018
23. Carroll C, Euhus R, Beaulieu N, et al: Hospital survival in rural markets: Closures, mergers, and profitability. *Health Aff (Millwood)* 2023; 42:498–507
24. Venkatesh AK, Janke A, Rothenberg C, et al: National trends in emergency department closures, mergers, and utilization, 2005-2015. *PLoS One* 2021; 16:e0251729
25. Congressional Research Service: The Strategic National Stockpile: Overview and Issues for Congress (R47400). 2023. Available at: https://crsreports.congress.gov/product/pdf/R/R47400. Accessed April 14, 2023