

Impact of the COVID-19 Pandemic on Regular Emergency Department Users

Olesya Baker, PhD; Alison Galbraith, MD, MPH; Ann Thomas, PhD; Robert F. LeCates, MA; and J. Frank Wharam, MD, MPH

The COVID-19 pandemic created barriers to obtaining health care services and disrupted patients' usual health care-seeking behavior.¹⁻⁶ The first peak in COVID-19 cases in the US in March 2020 was followed by a drastic decrease in emergency department (ED) visits,⁶⁻¹⁵ likely driven by stay-at-home orders, fear of acquiring COVID-19 infection in health care settings, and fewer referrals from outpatient office settings with reduced capacity.¹⁶⁻¹⁹

In the spring of 2020, the highest COVID-19 case rates in the US were largely concentrated in the Northeast, where Massachusetts and Connecticut were among the states recording the most new cases.²⁰ In response to rising cases, all New England states declared a state of emergency and instituted mandatory school closures, limits on gathering sizes, and public health messaging advising avoidance of unnecessary health care visits.²¹ These early stay-at-home measures are credited with saving lives and mitigating the spread of COVID-19,²² but they also profoundly changed health care-seeking behavior in the early stages of the pandemic. Vigilant public health monitoring combined with statewide protective measures enabled a gradual return to a "new normal" by the summer of 2020, further aided by subsequent vaccine rollout in 2021.

Although the effect of the COVID-19 pandemic on overall ED use in the US has been widely studied,^{6-15,17} less evidence exists on ED use during the pandemic among patients who engaged in regular prepandemic ED use.²³ Performing a robust, long-term analysis of early- and late-pandemic ED use in this population is important for several reasons. First, the pandemic delayed or deterred ED use for acute non-COVID-19 illnesses,^{9,15} raising concerns about increased downstream mortality or morbidity among patients who regularly use the ED for high-severity conditions requiring advanced diagnostic and treatment modalities. Second, the pandemic could serve as a catalyst for change among patients who had previous regular ED use for health concerns that could be effectively treated in lower-acuity care settings. Avoidance of ED care during the pandemic could stimulate regular ED users to address low-severity conditions via watchful waiting, telehealth, office visits, or other modalities. Results demonstrating a pandemic-related decline in ED use in this group of low-severity regular ED users could encourage and

ABSTRACT

OBJECTIVES: Regular users of the emergency department (ED) include both patients who could be better served in lower-acuity settings and those with high-severity conditions. ED use decreased during the COVID-19 pandemic, but patterns among regular ED users are unknown. To determine the impact of the COVID-19 pandemic on this population, we examined quarterly postpandemic ED utilization among prepandemic regular ED users. Key subgroups included prepandemic ED users with regular visits for (1) low-severity conditions and (2) high-severity conditions.

STUDY DESIGN: An event study design with COVID-19 and historic controls cohorts.

METHODS: We identified 4710 regular ED users at baseline and followed their ED utilization for 7 quarters. We used a generalized estimating equations model to compare the relative quarterly percent difference in ED visit rates between the COVID-19 and historic controls cohorts.

RESULTS: The first postpandemic quarter was associated with the largest decline in ED visits, at -36.0% (95% CI, -42.0% to -29.3%) per regular ED user overall, -52.2% (95% CI, -69.4% to -25.3%) among high-severity users, and -29.6% (95% CI, -39.8% to -17.8%) among low-severity users. However, use did not statistically differ from expected levels after 5 quarters among all regular ED users, 1 quarter among high-severity users, and 3 quarters among regular low-severity users.

CONCLUSIONS: Initial reductions among regular high-severity ED users raise concern for harm from delayed or missed care but did not result in increased high-severity visits later. Nonsustained declines among regular low-severity ED users suggest barriers to and opportunities for redirecting nonurgent ED use to lower-acuity settings.

Am J Manag Care. 2024;30(5):230-236. doi:10.37765/ajmc.2024.89540

inform expansion of COVID-19-era policies that incentivize less acute settings of care.

Previous literature defines the threshold for frequent ED use as 4 annual ED visits.²⁴⁻²⁶

This definition could include individuals who experience an intense health episode resulting in a high number of ED visits within a short time window, followed by recovery and lack of subsequent ED use. We introduce a novel definition of regular ED use that requires regular ED use sustained over the course of a year. Such patients may be better candidates for interventions aimed at diverting nonurgent ED use than patients whose ED use is frequent but short-lived.

Previous investigations of ED use during the COVID-19 pandemic primarily utilized data from a single center or hospital,^{8-12,14} which has limited ability to follow individuals across multiple EDs and over time. In this study, we used claims and enrollment data from a large New England commercial insurer and required continuous enrollment for 1 year before and 21 months after the start of the pandemic. A long pandemic period allowed us to study the early vs later effects of the pandemic among prepandemic regular ED users.

We sought to examine how regular users' ED visits evolved in the 4 quarters before and 7 quarters after the onset of the COVID-19 pandemic compared with a cohort of historic controls. We analyzed ED utilization patterns for regular ED users overall and for regular ED users with prepandemic (1) regular high-severity ED use and (2) regular low-severity ED use. Analyzing quarterly ED use enabled us to assess changes that occurred during the initial 3 months after the pandemic onset (characterized by stringent public health restrictions) as well as the subsequent pattern after easing of restrictions.

METHODS

Data Source and Population Setting

Using insurance claims and enrollment data from a large New England nonprofit health insurer, we performed a retrospective, longitudinal study of ED visits made by commercially insured members.

Our definition of regular ED user aimed to capture a small proportion of patients who regularly use a disproportionately large amount of ED resources. Two cohorts of regular ED users were selected for analysis: a COVID-19 cohort and historic controls. We defined the COVID-19 cohort as patients with at least 1 ED visit in at least 3 quarters of the baseline prepandemic year (March 2019–February 2020). In an analogous period 2 years earlier (March 2017–February 2018), we used the same regular ED user definition to capture a cohort of historic controls. We chose quarters as the unit of time measurement to capture enough ED visits per period and to optimize the stability of ED use trends over the baseline year. The percentages of patients with at least 1 ED visit in 1, 2, 3, or 4 quarters at baseline are displayed in [eAppendix Table 1](#) (eAppendix available at [ajmc.com](#)).

TAKEAWAY POINTS

- ▶ The COVID-19 pandemic transiently reduced emergency department (ED) use among prepandemic regular ED users.
- ▶ Among regular high-severity ED users, reductions in high-severity ED use during the first 3 months of the pandemic were not followed by higher downstream ED use.
- ▶ Among regular low-severity ED users, initial decreases in low-severity ED use highlight the potential to reduce this type of utilization.
- ▶ Patients with regular high-severity ED use might benefit from outreach efforts when ED access is limited, whereas patients with regular low-severity ED use might require safe and viable alternative health care access options.

We followed both cohorts for the subsequent 7 quarters. We measured ED utilization during the follow-up period among historic controls (April 2018–December 2019) to establish the expected pattern of ED utilization to compare with the COVID-19 cohort during the pandemic period (April 2020–December 2021). With the effects of the pandemic escalating rapidly between early and late March 2020, we designated this month as a transition period and excluded it from analyses. March 2018 was likewise excluded for the historic controls.

Only intervention and control patients with continuous enrollment for their respective study periods were included. We analyzed patients of all ages, including those covered by Medicare Advantage and Medicare supplement plans. ED visits for patients with such supplement plans are captured in our data because traditional Medicare reimburses 80% of the Medicare-approved amount for ED services, with the remaining ED claims paid by supplemental plans.²⁷

To measure race and ethnicity, the health plan uses a hierarchical combination of (1) self-reported data, (2) data from hospitals and health systems, and (3) predicted race and ethnicity based on the RAND Bayesian Improved Surname Geocoding method that integrates surname and residential address data to generate patient-level estimates of race and ethnicity.²⁸ We obtained household income estimates from the 2018 American Community Survey linked to the census tract of the patient's residence.²⁹ To classify ED visits by medical urgency, we applied the New York University ED visit severity algorithm validated to predict hospital admissions and mortality as adapted by the Johns Hopkins ACG System version 12.1.^{30,31} ED visit types were categorized based on the primary diagnosis. We defined ED visits to be low severity if they were classified as nonemergent, emergent primary care treatable, or nonsevere injury and to be high severity if they were classified as emergent, ED care needed, or severe injury.

Using these ED visit types, we created 2 subgroups of prepandemic ED users: regular low-severity and regular high-severity ED users. The regular low-severity ED user subgroup included patients who had at least 3 baseline quarters with at least 1 low-severity ED visit per quarter, resulting in a minimum of 3 low-severity ED visits at baseline. We defined the regular high-severity ED user subgroup as patients who had at least 3 baseline quarters with at least 1 high-severity ED visit per quarter, resulting in a minimum of 3 high-severity

ED visits at baseline. Individuals who had the required number of both low- and high-severity ED visits at baseline were included in both cohorts. In a sensitivity analysis, we excluded patients who were simultaneously regular high- and low-severity ED users at baseline (eAppendix Table 2).

Outcome Measures

The primary outcome was the number of ED visits of any severity per member per quarter for the COVID-19 cohort and historic controls. In subgroup analyses, the outcomes were the number of low-severity and high-severity ED visits per member per quarter for the regular low- and high-severity user subgroups, respectively.

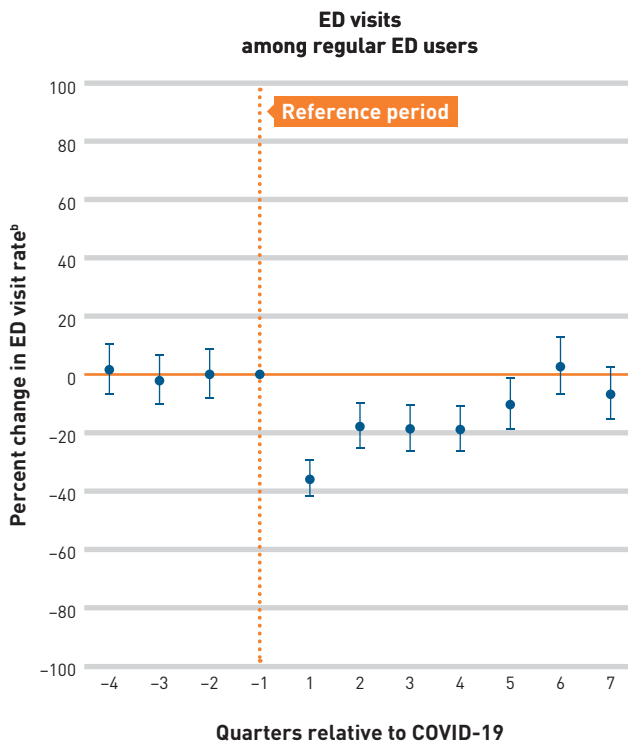
Statistical Analyses

We employed an event study approach to examine the evolution of patient-level quarterly ED visits in the COVID-19 cohort relative to historic controls. This approach assesses the difference in ED use between study groups at each time point relative to the difference at a referent quarter. Our model included a COVID-19 cohort indicator variable, quarterly indicator variables measuring time, and an interaction between the COVID-19 cohort and time indicators. To adjust for differing study group characteristics, we controlled for age, gender, race, and income. The omitted time variable (referent) was the last quarter prior to COVID-19 onset (December 2019-February 2020) and the equivalent quarter for historic controls (December 2017-February 2018). We tested the statistical significance of the interaction terms, which provide the change in outcome in the COVID-19 cohort relative to historic controls during a given quarter, as measured from the quarter immediately prior to the pandemic onset. We tested whether ED visit rates for the COVID-19 cohort and historic controls had similar trends prior to the pandemic by assessing the magnitude and significance of the coefficients associated with the first 3 pre-pandemic quarters. We also tested for baseline trend differences using a linear quarterly time trend term interacted with an indicator variable for the COVID-19 cohort (eAppendix Table 3).

To account for correlation in repeated measurements within each patient over time, we used generalized estimating equations models with an exchangeable correlation structure and robust SEs. Raw regression output is reported with exponentiated coefficients that can be interpreted as incidence rate ratios (eAppendix Table 4). To provide intuitive event study estimates, we computed the relative percent difference in ED visit rates between study groups at a given quarter by subtracting 1 from the exponentiated regression coefficients (Figures 1, 2, and 3 and eAppendix Table 5).³² We estimated ED visit rates and relative changes in ED visit rates between study groups at a given quarter using marginal estimation methods (eAppendix Tables 6 and 7). We used the same analytic approach to study changes in ED utilization for the 2 subgroups of regular ED users.

Statistical analyses were performed with SAS Studio Release 3.7 Enterprise Edition (SAS Institute Inc) and Stata/MP 16 (StataCorp

FIGURE 1. Adjusted Event Study Estimates of the Effects of the COVID-19 Pandemic on Percent Change in Quarterly ED Utilization by Regular ED Users^a



ED, emergency department.

^aThe figure presents event study estimates (dots) and 95% CIs (bars) of the effect of the COVID-19 pandemic on the percent change in the number of ED visits per patient per quarter before and after the onset of the pandemic. Pre- and postpandemic quarters were defined relative to March 2020. The event study reference period was the last pre-pandemic quarter. The model was estimated using generalized estimating equations with a log link and negative binomial family. We controlled for age at baseline, gender, race, and median household income at census tract level. Relative percent changes in ED visit rates between the COVID-19 cohort and historic controls were derived by subtracting 1 from the estimated incidence rate ratio event study coefficients.

^bVs quarter -1, COVID-19 vs historic controls cohort.

Source: Authors' analysis of patient-level claims data, March 2017-December 2019 [historic controls cohort] and March 2019-December 2021 [COVID-19 cohort].

LLC). This study was approved by the Harvard Pilgrim Health Care Institutional Review Board.

RESULTS

We identified 4710 patients who were regular ED users at baseline, which represents 3.5% of patients with any ED use at baseline but 17.8% (n=24,031) of all baseline ED visits. Of the regular ED users at baseline, 1830 (38.9%) were regular low-severity ED users, 333 (7.1%) were regular high-severity ED users, and 81 (1.7%) met the definition for both.

FIGURE 2. Adjusted Event Study Estimates of the Effects of the COVID-19 Pandemic on Percent Change in Quarterly Low-Severity ED Utilization by Regular Low-Severity ED Users^a

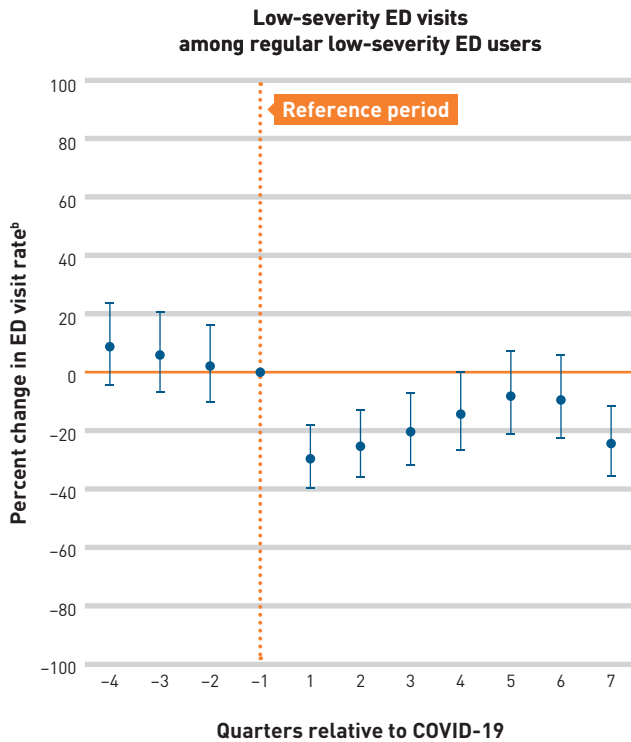
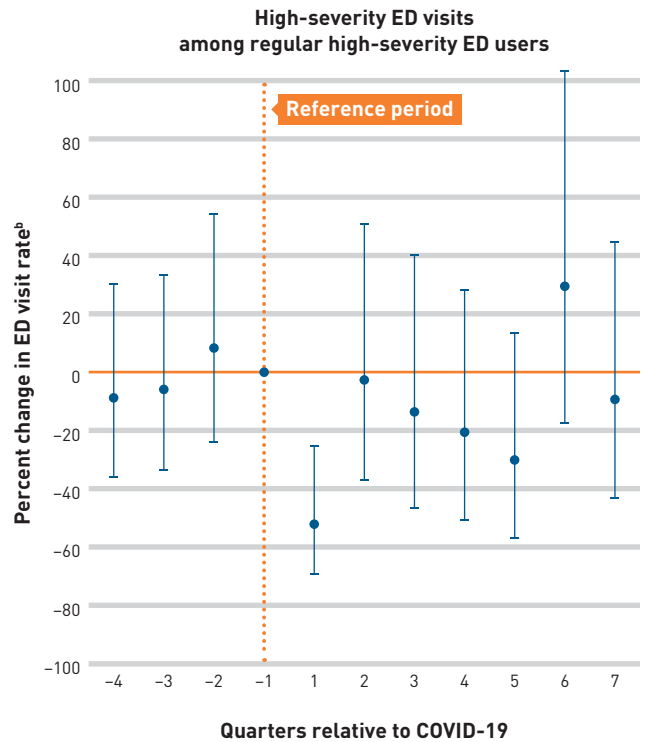


FIGURE 3. Adjusted Event Study Estimates of the Effects of the COVID-19 Pandemic on Percent Change in Quarterly High-Severity ED Utilization by Regular High-Severity ED Users^a



ED, emergency department.

^aThe figure presents event study estimates [dots] and 95% CIs [bars] of the effect of the COVID-19 pandemic on the percent change in the number of low-severity ED visits per patient per quarter before and after the onset of the pandemic. Pre- and postpandemic quarters were defined relative to March 2020. The event study reference period was the last prepandemic quarter. Low-severity visits included ED visits classified by the Johns Hopkins ACG System version 12.1 algorithm as nonemergent, emergent primary care treatable, or nonsevere injury. The model was estimated using generalized estimating equations with a log link and negative binomial family. We controlled for age at baseline, gender, race, and median household income at census tract level. Relative percent changes in low-severity ED visit rates between the COVID-19 cohort and historic controls were derived by subtracting 1 from the estimated incidence rate ratio event study coefficients.

^bVs quarter -1, COVID-19 vs historic controls cohort.

Source: Authors' analysis of patient-level claims data, March 2017–December 2019 [historic controls cohort] and March 2019–December 2021 [COVID-19 cohort].

ED, emergency department.

^aThe figure presents event study estimates [dots] and 95% CIs [bars] of the effect of the COVID-19 pandemic on the percent change in the number of high-severity ED visits per patient per quarter before and after the onset of the pandemic. Pre- and postpandemic quarters were defined relative to March 2020. The event study reference period was the last prepandemic quarter. High-severity visits included ED visits classified by the Johns Hopkins ACG System version 12.1 algorithm as emergent, ED care needed, or severe injury. The model was estimated using generalized estimating equations with a log link and negative binomial family. We controlled for age at baseline, gender, race, and median household income at census tract level. Relative percent changes in high-severity ED visit rates between the COVID-19 cohort and historic controls were derived by subtracting 1 from the estimated incidence rate ratio event study coefficients.

^bVs quarter -1, COVID-19 vs historic controls cohort.

Source: Authors' analysis of patient-level claims data, March 2017–December 2019 [historic controls cohort] and March 2019–December 2021 [COVID-19 cohort].

Sociodemographic characteristics of the COVID-19 cohort and historic controls were similar, except for a higher percentage of patients 65 years and older in the COVID-19 cohort (51.6%) than in the historic controls (43.6%), likely due to expansion of Medicare Advantage enrollment by the health plan in later years (Table 1).

Demographic characteristics across regular ED user subgroups differed significantly. Compared with regular low-severity ED users, regular high-severity ED users were older, were more likely to be male and White, and had a higher number of ED visits per member in the baseline year. Regular high-severity ED users had a mean of 7.9 ED visits per person at baseline, of which 4.4 were high severity,

2.9 were low severity, and the rest were classified as other ED visit types. Regular low-severity ED users had a mean of 5.9 ED visits per person in the baseline year, of which 4.7 were low-severity ED visits and 0.76 were high-severity ED visits, with the remainder classified as neither high nor low (Table 2).

In the baseline period, we found no significant differential trends in ED visit rates among the COVID-19 cohort vs historic controls for any of the 3 study groups (eAppendix Table 3). Among the COVID-19 cohort vs the historical control cohort, we found a large and significant decline in the rate of quarterly ED visits in the first quarter after the pandemic onset compared with the last

TABLE 1. Comparison of Baseline Demographic and Patient Characteristics Between the COVID-19 and Historic Controls Cohorts of Regular ED Users*

| Characteristic | COVID-19 cohort | Historic controls | P |
|--|-----------------|-------------------|--------|
| | n = 2270 | n = 2440 | |
| Age in years at baseline, mean (SE) | 59 (24) | 55 (25) | < .001 |
| Male, n (%) | 992 (43.70%) | 1048 (42.95%) | .60 |
| Race, n (%) | | | .30 |
| Black | 125 (5.51%) | 138 (5.66%) | |
| Hispanic | 69 (3.04%) | 99 (4.06%) | |
| Other | 21 (0.93%) | 21 (0.86%) | |
| White | 2055 (90.53%) | 2182 (89.43%) | |
| Median household income in \$, mean (SE) | 84,567 (32,282) | 84,376 (32,252) | .84 |
| Number of ED visits at baseline, mean (SE) | 5.05 (3.73) | 5.14 (4.28) | .44 |

ED, emergency department.

*The COVID-19 cohort of regular ED users was defined as patients with at least 1 ED visit in at least 3 quarters of the baseline prepandemic year (March 2019-February 2020). Historic controls were similarly defined using an analogous period 2 years earlier (March 2017-February 2018).

Source: Authors' analysis of patient-level claims data, March 2017-February 2018 and March 2019-February 2020. Individual-level race data were imputed using RAND's Bayesian Improved Surname Geocoding method. Income data are from the 2018 American Community Survey.

TABLE 2. Comparison of Baseline Demographic and Patient Characteristics Between Regular Low- vs High-Severity ED Users, Irrespective of Study Cohort*

| Characteristics | Low-severity users | High-severity users | P |
|---|--------------------|---------------------|--------|
| | n = 1911 | n = 414 | |
| Age in years at baseline, mean (SE) | 54 (26) | 67 (18) | < .001 |
| Male, n (%) | 759 (39.72%) | 203 (49.03%) | < .001 |
| Race, n (%) | | | .018 |
| Black | 108 (5.65%) | 13 (3.14%) | |
| Hispanic | 84 (4.40%) | 11 (2.66%) | |
| Other | 20 (1.05%) | 1 (0.24%) | |
| White | 1699 (88.91%) | 389 (93.96%) | |
| Median household income in \$, mean (SE) | 83,210 (31,921) | 85,555 (31,697) | .18 |
| Number of ED visits at baseline, any severity, mean (SE) | 5.91 (5.71) | 7.93 (9.95) | < .001 |
| Number of ED visits at baseline, low severity, mean (SE) | 4.66 (4.35) | 2.88 (8.38) | < .001 |
| Number of ED visits at baseline, high severity, mean (SE) | 0.76 (1.39) | 4.41 (1.9) | < .001 |

ED, emergency department.

*Regular low- or high-severity ED users were defined as patients with at least 1 low- or high-severity ED visit, respectively, in at least 3 quarters of the baseline year. Visits were determined to be low severity if they were classified as nonemergent, emergent primary care treatable, or nonsevere injury and to be high severity if they were classified as emergent, ED care needed, or severe injury according to the New York University ED visit severity algorithm validated to predict hospital admissions and mortality as adapted by the Johns Hopkins ACG System version 12.1.

Source: Authors' analysis of patient-level claims data, March 2017-February 2018 and March 2019-February 2020. Individual-level race data were imputed using RAND's Bayesian Improved Surname Geocoding method. Income data are from the 2018 American Community Survey.

prepandemic quarter, with the magnitude of declines becoming successively smaller in subsequent late-pandemic quarters (Figure 1). Specifically, among all regular ED users, we observed a decline of 36.0% (95% CI, -42.0% to -29.3%) in ED visits per patient in the first postpandemic quarter in the COVID-19 cohort relative to historic controls equivalent to an absolute level reduction of 0.24 ED visits per patient (95% CI, -0.33 to -0.15). In the following 4 quarters corresponding to July 2020 to June 2021, we found smaller magnitude but statistically significant reductions of 17.8% (95% CI, -25.4% to -9.4%), 18.8% (95% CI, -26.6% to -10.3%), 18.9% (95% CI, -26.5 to -10.4%), and 10.4% (95% CI, -18.8% to -1.1%) in ED visits per patient per quarter, respectively. We found no statistically detectable difference in ED visit rates between the COVID-19 cohort and historic controls by July through September 2021 or for October through December 2021.

Among the 2 regular ED user subgroups, regular high-severity ED users experienced the greatest first-quarter reduction with a decline of 52.2% (95% CI, -69.4% to -25.3%) in the number of high-severity ED visits per patient, corresponding to a level change of -0.27 high-severity ED visits per patient (95% CI, -0.57 to 0.02). Regular low-severity users experienced a 29.6% decline in low-severity ED visits in the first quarter after the pandemic onset (95% CI, -39.8% to -17.8%), corresponding to a level change of -0.12 low-severity ED visits per patient (95% CI, -0.25 to 0.01). High-severity regular users' ED utilization returned to expected ED use levels relatively quickly, with no significant difference in rates of high-severity ED use by the second postpandemic quarter (difference: -2.7%; 95% CI, -37.4% to 51.1%). Among low-severity regular users beyond the early-pandemic period, the magnitude of observed low-severity ED visit rates gradually increased toward no detectable difference by April through June 2021 but declined again to 24.4% below expected (95% CI, -35.7% to -11.3%) during October through December 2021.

A sensitivity analysis excluding patients 65 years and older to address the expansion of Medicare Advantage enrollment by the health plan produced comparable estimates (Appendix Table 8).

DISCUSSION

To our knowledge, this is the first study to assess long-term ED use during the COVID-19 pandemic among prepandemic regular ED users and the first to analyze pandemic-related changes among regular high- and low-severity ED users.

Our study adds several insights to the growing literature about postpandemic ED use. We observed major reductions in ED use among prepandemic regular ED users in the first 3 months after the pandemic onset. These initial postpandemic reductions could reflect patients with emergent needs forgoing necessary treatment, avoidance of the ED for nonemergency conditions, or displacement of ED care to other settings.

We found that the deterrent effect of the pandemic on high-severity ED utilization among regular high-severity users was relatively short-lived, with high-severity ED use returning to expected levels after only 3 months. Patients who rely on the ED for high-severity care could experience complications from the disruption of essential ED services. Although we did not observe higher-than-expected high-severity ED use later in the pandemic period, it is difficult to assess whether this was driven by a lack of pent-up demand, heterogeneity in ED use within the high-severity group, or limited follow-up duration.

Initial decreases in low-severity ED use among regular low-severity ED users highlight the potential to reduce low-severity ED use. However, further investigation is needed to determine what pandemic-related mechanisms were responsible for the reduction in low-severity ED visits and whether these patients had safe and viable options to obtain health care in alternative settings. A return to lower ED use during the last quarter spanning October through December 2021 coincided with the rise of the Omicron variant. This suggests that low-severity regular ED users may have taken pandemic severity into account when deciding on their health care access options. Whether the return to expected ED use among low-severity ED users was related to barriers to accessing alternative care is unclear; future research examining utilization of alternatives to ED care among regular ED users after the COVID-19 pandemic is warranted. Patients with both low- and high-severity regular ED use might be more chronically ill and exhibit differential patterns of ED use over time. However, the results were robust to exclusion of these patients from the low-severity group.

Limitations

Our study has several limitations. First, we examined ED trends only among enrollees with plans from a commercial carrier. Although privately insured enrollees are a diverse group in terms of medical risk factors, they may be younger, have higher incomes and fewer barriers to nonacute care access,^{33,34} and have higher baseline low-acuity ED utilization compared with publicly insured beneficiaries.

Second, by requiring continuous enrollment, we also excluded patients who died during the study period, who were likely to have been high-severity ED utilizers and less responsive to the

barriers created by the pandemic. Without them, our results might overestimate ED visit reductions during the COVID-19 period.

Finally, our study included members with insurance from a single carrier in New England, a region that had a unique pandemic trajectory, so our results may not generalize to other health plans or US regions.

CONCLUSIONS

In a New England commercially insured population, an early-pandemic decline in ED use among regular users was followed by a return to expected levels. Among patients with regular prepandemic ED utilization for high-severity care, a pandemic-related decline in high-severity ED use suggests the need for outreach during periods of highly restricted ED access to ensure appropriate levels of care. Although the initial decline in low-severity regular ED use suggests opportunities for redirecting such ED visits to alternative settings, it is unclear whether the return to expected ED use among low-severity ED users is related to barriers to accessing alternative care; future research examining utilization of alternatives to ED care among low-severity regular ED users after the COVID-19 pandemic is warranted. ■

Author Affiliations: Division of Health Policy and Insurance Research, Department of Population Medicine, Harvard Pilgrim Health Care Institute, Harvard Medical School (OB, AG, AT, RFL), Boston, MA; now with Department of Pediatrics, Boston Medical Center (AG), Boston, MA; Boston University Chobanian & Avedisian School of Medicine (AG), Boston, MA; Duke-Margolis Institute for Health Policy (JFW), Durham, NC.

Source of Funding: This study was funded by Harvard Pilgrim Health Care (now Point32Health) as part of a larger project (RECOVER: Understanding COVID-19 Impacts on Health Outcomes and Equity in the New England Region).

Author Disclosures: Dr Baker is employed by Harvard Pilgrim Health Care Institute and received research funding from Point32Health. Dr Galbraith was employed by Harvard Pilgrim Health Care Institute until February 2023 and received research funding from Harvard Pilgrim Health Care. The remaining authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

Authorship Information: Concept and design (OB, JFW); acquisition of data (OB, AG, AT, JFW); analysis and interpretation of data (OB, AG, AT, RFL, JFW); drafting of the manuscript (OB, JFW); critical revision of the manuscript for important intellectual content (OB, AG, RFL, JFW); statistical analysis (OB, JFW); obtaining funding (OB, AG, JFW); administrative, technical, or logistic support (OB, AG, AT, RFL, JFW); and supervision (OB, AG, JFW).

Address Correspondence to: Olesya Baker, PhD, Department of Population Medicine, Harvard Pilgrim Health Care Institute, Harvard Medical School, 401 Park St, Ste 401, Boston, MA 02215. Email: olesya_baker@hphci.harvard.edu.

REFERENCES

- Whaley CM, Pera MF, Cantor J, et al. Changes in health services use among commercially insured US populations during the COVID-19 pandemic. *JAMA Netw Open*. 2020;3(11):e2024984. doi:10.1001/jamanetworkopen.2020.24984
- Song H, Bergman A, Chen AT, et al. Disruptions in preventive care: mammograms during the COVID-19 pandemic. *Health Serv Res*. 2021;56(1):95-101. doi:10.1111/1475-6773.13596
- Weiner JP, Bandeian S, Hatf E, Lans D, Liu A, Lemke KW. In-person and telehealth ambulatory contacts and costs in a large US insured cohort before and during the COVID-19 pandemic. *JAMA Netw Open*. 2021;4(3):e212618. doi:10.1001/jamanetworkopen.2021.2618
- Birkmeyer JD, Barnato A, Birkmeyer N, Bessler R, Skinner J. The impact of the COVID-19 pandemic on hospital admissions in the United States. *Health Aff (Millwood)*. 2020;39(11):2010-2017. doi:10.1377/hlthaff.2020.00980
- Mafi JN, Craff M, Vangala S, et al. Trends in US ambulatory care patterns during the COVID-19 pandemic, 2019-2021. *JAMA*. 2022;327(3):237-247. doi:10.1001/jama.2021.24294
- Zhang J. Hospital avoidance and unintended deaths during the COVID-19 pandemic. *Am J Health Econ*. 2021;7(4):405-426. doi:10.1086/715158

7. Friedman AB, Barfield D, David G, et al. Delayed emergencies: the composition and magnitude of non-respiratory emergency department visits during the COVID-19 pandemic. *J Am Coll Emerg Physicians Open*. 2021;2(1):e12349. doi:10.1002/emp2.12349
8. Yu J, Hammond G, Waken RJ, Fox D, Joynt Maddox KE. Changes in non-COVID-19 emergency department visits by acuity and insurance status during the COVID-19 pandemic. *Health Aff (Millwood)*. 2021;40(6):896-903. doi:10.1377/hlthaff.2020.02464
9. Venkatesh AK, Janke AT, Shu-Xia L, et al. Emergency department utilization for emergency conditions during COVID-19. *Ann Emerg Med*. 2021;78(1):84-91. doi:10.1016/j.annemergmed.2021.01.011
10. Gutovitz S, Pangia J, Finer A, Rymer K, Johnson D. Emergency department utilization and patient outcomes during the COVID-19 pandemic in America. *J Emerg Med*. 2021;60(6):798-806. doi:10.1016/j.jemermed.2021.01.002
11. Lucero AD, Lee A, Hyun J, et al. Underutilization of the emergency department during the COVID-19 pandemic. *West J Emerg Med*. 2020;21(6):15-23. doi:10.5811/westjem.2020.8.48632
12. Giannouchos TV, Biskupiak J, Moss MJ, Brixner D, Andreyeva E, Ukert B. Trends in outpatient emergency department visits during the COVID-19 pandemic at a large, urban, academic hospital system. *Am J Emerg Med*. 2021;40:20-26. doi:10.1016/j.ajem.2020.12.009
13. Boserup B, McKenney M, Elkbuli A. The impact of the COVID-19 pandemic on emergency department visits and patient safety in the United States. *Am J Emerg Med*. 2020;38(9):1732-1736. doi:10.1016/j.ajem.2020.06.007
14. Jeffery MM, D'Onofrio G, Paek H, et al. Trends in emergency department visits and hospital admissions in health care systems in 5 states in the first months of the COVID-19 pandemic in the US. *JAMA Intern Med*. 2020;180(10):1328-1333. doi:10.1001/jamainternmed.2020.3288
15. Pines JM, Zocchi MS, Black BS, et al; US Acute Care Solutions Research Group. The effect of the COVID-19 pandemic on emergency department visits for serious cardiovascular conditions. *Am J Emerg Med*. 2021;47:42-51. doi:10.1016/j.ajem.2021.03.004
16. Kolata G. Amid the coronavirus crisis, heart and stroke patients go missing. *New York Times*. April 25, 2020. Updated November 2, 2020. Accessed November 14, 2022. <https://www.nytimes.com/2020/04/25/health/coronavirus-heart-stroke.html>
17. Hartnett KP, Kite-Powell A, DeVies J, et al; National Syndromic Surveillance Program Community of Practice. Impact of the COVID-19 pandemic on emergency department visits — United States, January 1, 2019–May 30, 2020. *MMWR Morb Mortal Wkly Rep*. 2020;69(23):699-704. doi:10.15585/mmwr.mm6923e1
18. Kocher KE, Macy ML. Emergency department patients in the early months of the coronavirus disease 2019 (COVID-19) pandemic—what have we learned? *JAMA Health Forum*. 2020;1(6):e200705. doi:10.1001/jamahealthforum.2020.0705
19. Wong LE, Hawkins JE, Langness S, Murrell KL, Iris P, Sammann A. Where are all the patients? addressing Covid-19 fear to encourage sick patients to seek emergency care. *NEJM Catal Innov Care Deliv*. May 14, 2020. Accessed December 5, 2022. <https://catalyst.nejm.org/doi/full/10.1056/CAT.20.0193>
20. Frey WH. One year in, COVID-19's uneven spread across the US continues. Brookings Institution. March 5, 2021. Accessed November 14, 2022. <https://www.brookings.edu/research/one-year-in-covid-19s-uneven-spread-across-the-us-continues/>
21. Hamann KM, Rosen MB, Conroy MA, MacGillivray SJ, Remes SR. COVID-19: quick state by state reference tool regarding reopening in New England states – updated January 4. *National Law Review*. January 4, 2021. Accessed November 14, 2022. <https://www.natlawreview.com/article/covid-19-quick-state-state-reference-tool-regarding-reopening-new-england-states>
22. Emanuel EJ, Persad G, Upshur R, et al. Fair allocation of scarce medical resources in the time of Covid-19. *N Engl J Med*. 2020;382(21):2049-2055. doi:10.1056/NEJMs2005114
23. Chou YC, Yen YF, Chu D, Hu HY. Impact of the COVID-19 pandemic on healthcare-seeking behaviors among frequent emergency department users: a cohort study. *Int J Environ Res Public Health*. 2021;18(12):6351. doi:10.3390/ijerph18126351
24. Pines JM, Asplin BR, Kaji AH, et al. Frequent users of emergency department services: gaps in knowledge and a proposed research agenda. *Acad Emerg Med*. 2011;18(6):e64-e69. doi:10.1111/j.1553-2712.2011.01086.x
25. Doupe MB, Palatnick W, Day S, et al. Frequent users of emergency departments: developing standard definitions and defining prominent risk factors. *Ann Emerg Med*. 2012;60(1):24-32. doi:10.1016/j.annemergmed.2011.11.036
26. Kanzaria HK, Niedzwiecki MJ, Montoy JC, Raven MC, Hsia RY. Persistent frequent emergency department use: core group exhibits extreme levels of use for more than a decade. *Health Aff (Millwood)*. 2017;36(10):1720-1728. doi:10.1377/hlthaff.2017.0658
27. Summary of benefits: Harvard Pilgrim's Stride (HMO) Medicare Advantage plan. Harvard Pilgrim Health Care. 2018. Accessed December 5, 2022. <https://www.harvardpilgrim.org/broker/wp-content/uploads/sites/2/2018/09/2018-Summary-of-Benefits-MA.pdf>
28. Elliott MN, Fremont A, Morrison PA, Pantoja P, Lurie N. A new method for estimating race/ethnicity and associated disparities where administrative records lack self-reported race/ethnicity. *Health Serv Res*. 2008;43(5, pt 1):1722-1736. doi:10.1111/j.1475-6773.2008.00854.x
29. American Community Survey (ACS). US Census Bureau. Updated February 26, 2024. Accessed December 7, 2022. <https://www.census.gov/programs-surveys/acs>
30. Ballard DW, Price M, Fung V, et al. Validation of an algorithm for categorizing the severity of hospital emergency department visits. *Med Care*. 2010;48(1):58-63. doi:10.1097/MLR.0b013e3181bd49ad
31. Lemke KW, Pham K, Ravert DM, Weiner JP. A revised classification algorithm for assessing emergency department visit severity of populations. *Am J Manag Care*. 2020;26(3):119-125. doi:10.37765/ajmc.2020.42636
32. Ballinger GA. Using generalized estimating equations for longitudinal data analysis. *Organ Res Methods*. 2004;7(2):127-150. doi:10.1177/1094428104263672
33. Cunningham PJ. What accounts for differences in the use of hospital emergency departments across U.S. communities? *Health Aff (Millwood)*. 2006;25(5):w324-w336. doi:10.1377/hlthaff.25.w324
34. Cheung PT, Wiler JL, Lowe RA, Ginde AA. National study of barriers to timely primary care and emergency department utilization among Medicaid beneficiaries. *Ann Emerg Med*. 2012;60(1):4-10.e2. doi:10.1016/j.annemergmed.2012.01.035

Visit ajmc.com/link/89540 to download PDF and eAppendix

eAppendix

Contents:

eAppendix Table 1. Quarterly Frequency of ED Use Among Patients with Any ED Use at Baseline, COVID Cohort and Historic Controls

eAppendix Table 2. Adjusted GEE event study regression coefficients for regular low- and high-severity ED user cohorts excluding patients who were both high- and low-severity ED users at baseline

eAppendix Table 3. Pre-pandemic time trend analysis

eAppendix Table 4. Adjusted GEE event study regression coefficients

eAppendix Table 5. Estimated percent change in the number of ED visits per patient per quarter between the COVID cohort and Historic Controls relative to the last pre-pandemic quarter (Q4)

eAppendix Table 6. Adjusted marginal estimates from event study regression estimating the number of ED visits per person per quarter for the COVID cohort and Historic Controls

eAppendix Table 7. Adjusted marginal estimates from event study regression estimating the level change in the number of ED visits per person per quarter for the COVID cohort and Historic Controls relative to last pre-pandemic quarter

eAppendix Table 8. Adjusted GEE event study regression coefficients excluding patients 65 years old or older at baseline

eAppendix Table 1. Quarterly Frequency of ED Use Among Patients with Any ED Use at Baseline, COVID Cohort and Historic Controls

| | COVID cohort | | Historic Controls | |
|---|-------------------------------|--------------------------------|-------------------------------|--------------------------------|
| | Number (%) of Patients | Number (%) of ED Visits | Number (%) of Patients | Number (%) of ED Visits |
| Number of quarters with ≥ 1 ED visit per quarter at baseline | N=63,316 | N=93,622 | N=71,276 | N=104,281 |
| 1 quarter with ≥ 1 ED visit | 52,058 (82.2%) | 59,601 (63.6%) | 58,949 (82.7%) | 67,011 (64.2%) |
| 2 quarters with ≥ 1 ED visit | 8,988 (14.2%) | 22,550 (24.1%) | 9,887 (13.9%) | 24,708 (23.7%) |
| 3 quarters with ≥ 1 ED visit | 1,878 (2.9%) | 8,158 (8.7%) | 2,009 (2.8%) | 8,815 (8.4%) |
| 4 quarters with ≥ 1 ED visit | 392 (0.6%) | 3,313 (3.5%) | 431 (0.6%) | 3,747 (3.6%) |

Notes: For example, 2.9% of COVID cohort members with any ED visit at baseline had ≥ 1 ED visit(s) in at least 3 of 4 baseline quarters

eAppendix Table 2. Adjusted Generalized Estimating Equations Event Study Regression for Low- and High-Severity Regular ED User Cohorts Excluding Patients Who are Both Low- and High- Severity ED Users at Baseline.

| | (1) Low-Severity Regular ED Users | (2) High-Severity Regular ED Users |
|-------------------------------|---|--|
| | Regression Coefficients [95% CI] | Regression Coefficients [95% CI] |
| Historic Controls | Reference | Reference |
| COVID cohort | 0.939 [0.828,1.064] | 1.009 [0.749,1.358] |
| Q1 | 0.949 [0.856,1.052] | 1.118 [0.856,1.459] |
| Q2 | 0.936 [0.844,1.037] | 1.341* [1.033,1.742] |
| Q3 | 0.981 [0.886,1.087] | 1.060 [0.811,1.387] |
| Q4 | Reference | Reference |
| Q5 | 0.450*** [0.401,0.506] | 0.441*** [0.323,0.603] |
| Q6 | 0.430*** [0.382,0.484] | 0.329*** [0.235,0.459] |
| Q7 | 0.403*** [0.357,0.454] | 0.226*** [0.156,0.328] |
| Q8 | 0.400*** [0.355,0.451] | 0.258*** [0.180,0.368] |
| Q9 | 0.369*** [0.326,0.416] | 0.290*** [0.205,0.409] |
| Q10 | 0.364*** [0.322,0.411] | 0.209*** [0.143,0.306] |
| Q11 | 0.391*** [0.346,0.440] | 0.262*** [0.184,0.374] |
| Historic Controls # Q4 | Reference | Reference |

| | | |
|---|---|---------------------------------------|
| COVID cohort # Q1 | 1.074 [0.923,1.250] | 0.889 [0.600,1.316] |
| COVID cohort # Q2 | 1.061 [0.912,1.236] | 0.930 [0.634,1.365] |
| COVID cohort # Q3 | 1.009 [0.867,1.174] | 1.109 [0.751,1.637] |
| COVID cohort # Q5 | 0.627*** [0.521,0.753] | 0.544* [0.331,0.896] |
| COVID cohort # Q6 | 0.741** [0.618,0.888] | 0.836 [0.507,1.381] |
| COVID cohort # Q7 | 0.766** [0.638,0.920] | 0.897 [0.515,1.560] |
| COVID cohort # Q8 | 0.834* [0.696,1.000] | 0.648 [0.368,1.141] |
| COVID cohort # Q9 | 0.920 [0.766,1.104] | 0.681 [0.397,1.167] |
| COVID cohort # Q10 | 0.880 [0.732,1.059] | 1.328 [0.779,2.265] |
| COVID cohort # Q11 | 0.752** [0.625,0.906] | 0.779 [0.453,1.339] |
| Male | 0.933 [0.858,1.016] | 0.953 [0.814,1.115] |
| Hispanic | 0.920 [0.702,1.204] | 0.965 [0.539,1.728] |
| Other | 1.038 [0.671,1.606] | 0.507 [0.0806,3.190] |
| White | 0.989 [0.816,1.200] | 0.742 [0.495,1.113] |
| Age | 1.001 [1.000,1.003] | 0.998 [0.994,1.002] |
| Median Household Income (in 1,000) | 1.000 | 0.999 |

| | | |
|--------------|---------------|---------------|
| | [0.999,1.001] | [0.996,1.001] |
| Observations | 20350 | 3949 |

Exponentiated coefficients; 95% confidence intervals in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

eAppendix Table 3. Pre-Pandemic Time Trend Analysis

| | (1) All Reg Users | (3) Low Severity | (5) High Severity |
|--|-----------------------------|----------------------------|-----------------------------|
| | Regression | Regression | Regression |
| | Coefficients | Coefficients | Coefficients |
| Historic Controls | Reference | Reference | Reference |
| COVID Cohort | 0.982 [0.899.1.073] | 1.048 [0.913.1.204] | 0.893 [0.644.1.238] |
| Quarter | 1.007 [0.989.1.026] | 1.018 [0.991.1.046] | 0.953 [0.876.1.037] |
| COVID Cohort # | 0.997 [0.971.1.025] | 0.972 [0.934.1.011] | 1.043 [0.925.1.176] |
| Male | 0.993 [0.938.1.050] | 1.015 [0.920.1.119] | 0.972 [0.853.1.107] |
| Hispanic | 0.929 [0.764.1.130] | 0.869 [0.632.1.196] | 0.962 [0.557.1.662] |
| Other | 1.126 [0.821.1.544] | 1.073 [0.645.1.784] | 0.702 [0.152.3.241] |
| White | 1.000 [0.877.1.141] | 1.002 [0.799.1.255] | 0.960 [0.653.1.411] |
| Age | 1.001 [1.000.1.002] | 1.001 [0.999.1.003] | 0.998 [0.995.1.002] |
| Median Household (in \$1,000) | 1.000 [0.999.1.001] | 1.000 [0.999.1.002] | 1.000 [0.997.1.002] |
| Observations | 18676 | 7584 | 1652 |

Exponentiated coefficients; 95% confidence intervals in brackets

*p<0.05, **p<0.01, ***p<0.001

Source: Authors' analysis of patient-level claims data, March 2017 – February 2018 and March 2019 – February 2020.

Notes: Time trend estimates and 95% confidence intervals. To test for divergence in ED utilization trends in the four pre-pandemic quarters, we used a Generalized Estimating Equations model with log link and Negative Binomial family with a linear quarterly time trend and an interaction between time trend and COVID cohort. Displayed coefficients are exponentiated to report Incidence Rate Ratios. We controlled for age at baseline, gender, race, and median

household income at census tract level. COVID cohort variable is a dummy that equals 1 for the COVID cohort and 0 for Historic Controls. Regular low- or high-severity ED users were defined as patients with at least one low or high severity ED visit, respectively, in at least three quarters of the baseline year. Visits were determined to be low severity if they were classified as non-emergent, emergent primary care treatable or non-severe injury by the ACG algorithm. Visits were determined to be high severity if they were classified as emergent, ED care needed or severe injury. Individual-level race data was imputed using RAND's Bayesian Improved Surname Geocoding method. Income data are from the 2018 American Community Survey.

eAppendix Table 4. Adjusted Generalized Estimating Equations Event Study Regression Coefficients

| | (1) All Reg Users | (2) Low Severity | (3) High Severity |
|--------------------------|--|--|--|
| | Regression Coefficients [95% CI] | Regression Coefficients [95% CI] | Regression Coefficients [95% CI] |
| Historic Controls | Reference | Reference | Reference |
| COVID cohort | 0.976 [0.904,1.054] | 0.938 [0.829,1.061] | 1.018 [0.773,1.339] |
| Q1 | 0.978 [0.921,1.039] | 0.953 [0.871,1.043] | 1.100 [0.856,1.411] |
| Q2 | 1.035 [0.975,1.098] | 0.950 [0.868,1.039] | 1.292* [1.011,1.651] |
| Q3 | 1.044 [0.983,1.108] | 0.981 [0.897,1.073] | 1.077 [0.838,1.383] |
| Q4 | Reference | Reference | Reference |
| Q5 | 0.568*** [0.532,0.606] | 0.475*** [0.430,0.525] | 0.505*** [0.381,0.670] |
| Q6 | 0.532*** [0.498,0.568] | 0.460*** [0.415,0.509] | 0.348*** [0.256,0.473] |
| Q7 | 0.471*** [0.440,0.504] | 0.416*** [0.375,0.461] | 0.257*** [0.184,0.359] |
| Q8 | 0.494*** [0.462,0.528] | 0.408*** [0.367,0.452] | 0.280*** [0.202,0.388] |
| Q9 | 0.474*** [0.443,0.507] | 0.393*** [0.353,0.436] | 0.289*** [0.210,0.399] |
| Q10 | 0.458*** [0.428,0.490] | 0.378*** [0.340,0.421] | 0.274*** [0.197,0.380] |
| Q11 | 0.473*** [0.442,0.506] | 0.399*** [0.359,0.443] | 0.284*** [0.205,0.393] |

| Historic Controls # Q4 | Reference | Reference | Reference |
|-------------------------------|---|---|--|
| COVID cohort # Q1 | 1.016 [0.931,1.109] | 1.087 [0.953,1.239] | 0.912 [0.637,1.305] |
| COVID cohort # Q2 | 0.979 [0.898,1.068] | 1.059 [0.929,1.208] | 0.944 [0.664,1.341] |
| COVID cohort # Q3 | 1.000 [0.917,1.091] | 1.021 [0.895,1.164] | 1.082 [0.758,1.545] |
| COVID cohort # Q5 | 0.640*** [0.580,0.707] | 0.704*** [0.602,0.822] | 0.478** [0.306,0.747] |
| COVID cohort # Q6 | 0.822*** [0.746,0.906] | 0.746*** [0.639,0.871] | 0.973 [0.626,1.511] |
| COVID cohort # Q7 | 0.812*** [0.734,0.897] | 0.796** [0.680,0.931] | 0.863 [0.530,1.405] |
| COVID cohort # Q8 | 0.811*** [0.735,0.896] | 0.857 [0.733,1.002] | 0.794 [0.491,1.285] |
| COVID cohort # Q9 | 0.896* [0.812,0.989] | 0.918 [0.785,1.073] | 0.698 [0.429,1.137] |
| COVID cohort # Q10 | 1.028 [0.932,1.134] | 0.907 [0.775,1.063] | 1.294 [0.824,2.034] |
| COVID cohort # Q11 | 0.930 [0.843,1.026] | 0.756*** [0.643,0.887] | 0.906 [0.567,1.450] |
| Male | 0.972 [0.920,1.026] | 1.011 [0.920,1.112] | 0.955 [0.823,1.108] |
| Hispanic | 0.962 [0.796,1.163] | 0.858 [0.630,1.168] | 0.917 [0.506,1.661] |
| Other | 1.019 [0.745,1.392] | 1.034 [0.630,1.696] | 0.545 [0.0828,3.589] |
| White | 0.995 [0.876,1.131] | 1.001 [0.805,1.245] | 0.817 [0.538,1.240] |
| Age | 1.001* | 1.001 | 0.997 |

| | | | |
|--------------------------------|---------------|---------------|---------------|
| | [1.000,1.003] | [0.999,1.003] | [0.993,1.001] |
| Median Household Income | 1.000 | 1.000 | 0.999 |
| (in \$1,000) | [0.999,1.001] | [0.999,1.002] | [0.996,1.001] |
| Observations | 51359 | 20856 | 4543 |

Exponentiated coefficients; 95% confidence intervals in brackets

*p<0.05, **p<0.01, ***p<0.001

Source: Authors' analysis of patient-level claims data, March 2017 – December 2019 and March 2019 – December 2021.

Notes: Event study estimates and 95% confidence intervals. The model was estimated using Generalized Estimating Equations with log link and Negative Binomial family. Displayed coefficients are exponentiated to report Incidence Rate Ratios. We controlled for age at baseline, gender, race, and median household income at census tract level. COVID cohort variable is a dummy that equals 1 for the COVID cohort and 0 for Historic Controls. Q1 represents the first quarter of the baseline period. The event study reference period was Q4, the last baseline quarter. Q5 corresponds to the first post-pandemic quarter, and the term COVID cohort#Q5 represents the relative difference between the COVID cohort and Historic Controls in Q5 relative to Q4. Regular low- or high-severity ED users were defined as patients with at least one low or high severity ED visit, respectively, in at least three quarters of the baseline year. Visits were determined to be low severity if they were classified as non-emergent, emergent primary care treatable or non-severe injury by the ACG algorithm. Visits were determined to be high severity if they were classified as emergent, ED care needed or severe injury. Individual-level race data was imputed using RAND's Bayesian Improved Surname Geocoding method. Income data are from the 2018 American Community Survey.

eAppendix Table 5. Estimated Percent Change in the Number of ED visits per Patient per Quarter Between the COVID Cohort and Historic Controls Relative to the Last Pre-Pandemic Quarter (Q4)

| | All Regular ED Users | Regular Low-Severity ED Users | Regular High-Severity ED Users |
|------------|--|--|--|
| Q1 | 1.6% [-6.9; 10.9] | 8.7% [-4.7; 23.9] | -8.8% [-36.3; 30.5] |
| Q2 | -2.1% [-10.2; 6.8] | 5.9% [-7.1; 20.8] | -5.6% [-33.6; 34.1] |
| Q3 | 0.0% [-8.3; 9.1] | 2.1% [-10.5; 16.4] | 8.2% [-24.2; 54.5] |
| Q4 | Reference | Reference | Reference |
| Q5 | -36.0% [-42.0; -29.3] | -29.6% [-39.8; -17.8] | -52.2% [-69.4; -25.3] |
| Q6 | -17.8% [-25.4; -9.4] | -25.4% [-36.1; -12.9] | -2.7% [-37.4; 51.1] |
| Q7 | -18.8% [-26.6; -10.3] | -20.4% [-32.0; -6.9] | -13.7% [-47.0; 40.5] |
| Q8 | -18.9% [-26.5; -10.4] | -14.3% [-26.7; 0.2] | -20.6% [-50.9; 28.5] |
| Q9 | -10.4% [-18.8; -1.1] | -8.2% [-21.5; 7.3] | -30.2% [-57.1; 13.7] |
| Q10 | 2.8% [-6.8; 13.4] | -9.3% [-22.5; 6.3] | 29.4% [-17.6; 103.4] |
| Q11 | -7.0% [-15.7; 2.6] | -24.4% [-35.7; -11.3] | -9.4% [-43.3; 45.0] |

eAppendix Table 6. Adjusted Marginal Estimates from Event Study Regression Estimating the Number of ED Visits Per Person Per Quarter for the COVID Cohort and Historic Controls

| Number of ED Visits Per Person Per Quarter | | | | | | |
|--|----------------------|--------------|-------------------------------|--------------|--------------------------------|--------------|
| | All Regular ED Users | | Regular Low-Severity ED Users | | Regular High-Severity ED Users | |
| | Historic Controls | COVID Cohort | Historic Controls | COVID Cohort | Historic Controls | COVID Cohort |
| Q1 | 1.24 | 1.24 | 1.16 | 1.18 | 1.09 | 1.01 |
| Q2 | 1.32 | 1.26 | 1.15 | 1.14 | 1.28 | 1.22 |
| Q3 | 1.33 | 1.30 | 1.19 | 1.14 | 1.06 | 1.17 |
| Q4 | 1.27 | 1.24 | 1.21 | 1.14 | 0.99 | 1.00 |
| Q5 | 0.72 | 0.45 | 0.58 | 0.38 | 0.50 | 0.24 |
| Q6 | 0.68 | 0.54 | 0.56 | 0.39 | 0.35 | 0.34 |
| Q7 | 0.60 | 0.48 | 0.50 | 0.38 | 0.26 | 0.22 |
| Q8 | 0.63 | 0.50 | 0.49 | 0.4 | 0.28 | 0.22 |
| Q9 | 0.60 | 0.53 | 0.48 | 0.41 | 0.29 | 0.20 |
| Q10 | 0.58 | 0.59 | 0.46 | 0.39 | 0.27 | 0.36 |
| Q11 | 0.60 | 0.55 | 0.48 | 0.34 | 0.28 | 0.26 |

Source: Authors' analysis of patient-level claims data, March 2017 – December 2019 and March 2019 – December 2021.

Notes: Estimates were obtained after the event study regression using the average marginal effects approach over each study, with cohort as the binary covariate. Pre- and post-pandemic quarters were defined relative to March 2020. The event study regression model was estimated using Generalized Estimating Equations with log link and Negative Binomial family. The event study reference period was the last pre-pandemic quarter.

eAppendix Table 7. Adjusted Marginal Estimates from Event Study Regression Estimating the Level Change in the Number of ED Visits Per Person Per Quarter for the COVID Cohort and Historic Controls Relative to Last Pre-Pandemic Quarter

| | Change in ED Visit Rate, COVID Cohort vs Historic Controls, relative to Q4 | | |
|------------|--|--------------------------------------|---------------------------------------|
| | All Regular ED Users | Regular Low-Severity ED Users | Regular High-Severity ED Users |
| Q1 | 0.02 [-0.09; 0.13] | 0.10 [-0.06; 0.25] | -0.10 [-0.46; 0.27] |
| Q2 | -0.03 [-0.14; 0.08] | 0.07 [-0.09; 0.22] | -0.07 [-0.46; 0.33] |
| Q3 | 0.00 [-0.11; 0.11] | 0.02 [-0.13; 0.18] | 0.09 [-0.29; 0.47] |
| Q4 | Reference | Reference | Reference |
| Q5 | -0.24 [-0.33; -0.15] | -0.12 [-0.25; 0.01] | -0.27 [-0.57; 0.02] |
| Q6 | -0.10 [-0.20; -0.01] | -0.09 [-0.22; 0.04] | -0.02 [-0.31; 0.27] |
| Q7 | -0.09 [-0.19; -0.00] | -0.05 [-0.18; 0.08] | -0.05 [-0.33; 0.23] |
| Q8 | -0.10 [-0.19; -0.01] | -0.02 [-0.15; 0.11] | -0.07 [-0.35; 0.21] |
| Q9 | -0.05 [-0.14; 0.05] | 0.01 [-0.12; 0.14] | -0.10 [-0.38; 0.18] |
| Q10 | 0.03 [-0.06; 0.12] | 0.01 [-0.12; 0.14] | 0.07 [-0.22; 0.35] |
| Q11 | -0.03 [-0.12; 0.07] | -0.07 [-0.20; 0.07] | -0.04 [-0.32; 0.24] |

Source: Authors' analysis of patient-level claims data, March 2017 – December 2019 and March 2019 – December 2021.

Notes: Estimates were obtained after the event study regression using the average marginal effects approach over each study quarter relative to last pre-COVID quarter, with cohort as the binary covariate over which the derivative was calculated. Pre- and post-

pandemic quarters were defined relative to March 2020. The event study regression model was estimated using Generalized Estimating Equations with log link and Negative Binomial family. The event study reference period was the last pre-pandemic quarter.

eAppendix Table 8. Adjusted Generalized Estimating Equations Event Study Regression Coefficients Excluding Patients 65 Years Old or Older at Baseline.

| | (1) | (2) | (3) |
|-------------------|---------------------------|---------------------------|---------------------------|
| | All Reg Users | Low Severity | High Severity |
| | Regression | Regression | Regression |
| | Coefficients | Coefficients | Coefficients |
| | [95% CI] | [95% CI] | [95% CI] |
| Historic Controls | Reference | Reference | Reference |
| COVID cohort | 0.962 [0.864,1.071] | 0.939 [0.800,1.103] | 1.080 [0.698,1.672] |
| Q1 | 0.954 [0.885,1.030] | 0.947 [0.849,1.056] | 1.038 [0.723,1.491] |
| Q2 | 1.023 [0.949,1.103] | 0.949 [0.852,1.059] | 1.138 [0.795,1.628] |
| Q3 | 1.034 [0.959,1.115] | 0.993 [0.891,1.107] | 1.070 [0.746,1.535] |
| Q4 | Reference | Reference | Reference |
| Q5 | 0.570*** [0.525,0.619] | 0.506*** [0.448,0.570] | 0.498*** [0.332,0.747] |
| Q6 | 0.538*** [0.495,0.584] | 0.476*** [0.421,0.537] | 0.326*** [0.208,0.509] |
| Q7 | 0.464*** [0.426,0.505] | 0.449*** [0.397,0.508] | 0.209*** [0.126,0.347] |

| | | | |
|------------------------|---|--|---------------------------|
| Q8 | 0.495*** [0.455,0.539] | 0.448*** [0.396,0.507] | 0.257*** [0.159,0.414] |
| Q9 | 0.455*** [0.417,0.495] | 0.418*** [0.369,0.474] | 0.305*** [0.194,0.481] |
| Q10 | 0.425*** [0.390,0.464] | 0.405*** [0.357,0.460] | 0.293*** [0.185,0.464] |
| Q11 | 0.460*** [0.423,0.501] | 0.401*** [0.353,0.455] | 0.352*** [0.227,0.546] |
| Historic Controls # Q4 | Reference | Reference | Reference |
| COVID cohort # Q1 | 1.003 [0.893,1.126] | 1.091 [0.928,1.284] | 0.897 [0.512,1.569] |
| COVID cohort # Q2 | 0.922 [0.822,1.035] | 1.025 [0.871,1.206] | 0.893 [0.513,1.554] |
| COVID cohort # Q3 | 0.975 [0.869,1.094] | 0.952 [0.809,1.121] | 0.898 [0.514,1.569] |
| COVID cohort # Q5 | 0.692*** [0.607,0.789] | 0.738** [0.611,0.891] | 0.531 [0.268,1.050] |
| COVID cohort # Q6 | 0.784*** [0.689,0.893] | 0.756** [0.625,0.915] | 1.230 [0.632,2.394] |
| COVID cohort # Q7 | 0.877 | 0.783* | 1.120 |

| | | | |
|----------------------------|--|---|------------------------|
| | [0.769,1.001] | [0.646,0.949] | [0.523,2.401] |
| COVID cohort # Q8 | 0.817** [0.716,0.931] | 0.763** [0.629,0.925] | 0.564 [0.249,1.279] |
| COVID cohort # Q9 | 0.977 [0.858,1.114] | 0.888 [0.733,1.075] | 0.646 [0.304,1.370] |
| COVID cohort # Q10 | 1.056 [0.926,1.204] | 0.836 [0.688,1.016] | 1.165 [0.585,2.319] |
| COVID cohort # Q11 | 0.892 [0.782,1.018] | 0.699*** [0.571,0.855] | 0.674 [0.329,1.379] |
| Male | 0.983 [0.906,1.065] | 1.083 [0.952,1.233] | 1.023 [0.787,1.328] |
| Hispanic | 0.983 [0.776,1.245] | 0.877 [0.612,1.258] | 0.641 [0.280,1.470] |
| Other | 1.027 [0.702,1.501] | 1.077 [0.618,1.877] | NA |
| White | 1.038 [0.869,1.240] | 1.053 [0.798,1.389] | 0.647 [0.350,1.196] |
| Age | 1.004*** [1.002,1.006] | 1.004* [1.000,1.007] | 0.994 [0.986,1.002] |
| Median Household Income | 1.000 | 0.999 | 0.998 |

| | | | |
|--------------|---------------|---------------|---------------|
| (in \$1,000) | [0.998,1.001] | [0.997,1.002] | [0.994,1.002] |
| Observations | 26675 | 12155 | 1760 |

Exponentiated coefficients; 95% confidence intervals in brackets

*p<0.05, **p<0.01, ***p<0.001

Source: Authors' analysis of patient-level claims data, March 2017 – December 2019 and March 2019 – December 2021.

Notes: Event study estimates and 95% confidence intervals. The model was estimated using Generalized Estimating Equations with log link and Negative Binomial family. Displayed coefficients are exponentiated to report Incidence Rate Ratios. We controlled for age at baseline, gender, race, and median household income at census tract level. COVID cohort variable is a dummy that equals 1 for the COVID cohort and 0 for Historic Controls. Q1 represents the first quarter of the baseline period. The event study reference period was Q4, the last baseline quarter. Q5 corresponds to the first post-pandemic quarter, and the term COVID cohort#Q5 represents the relative difference between the COVID cohort and Historic Controls in Q5 relative to Q4. Regular low- or high-severity ED users were defined as patients with at least one low or high severity ED visit, respectively, in at least three quarters of the baseline year. Visits were determined to be low severity if they were classified as non-emergent, emergent primary care treatable or non-severe injury by the ACG algorithm. Visits were determined to be high severity if they were classified as emergent, ED care needed or severe injury. Individual-level race data was imputed using RAND's Bayesian Improved Surname Geocoding method. Income data are from the 2018 American Community Survey.