

Changes in Pediatric Intensive Care Admissions in Wisconsin During the 2020 COVID-19 Pandemic

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ABSTRACT

Background: We perceived changes in the frequency of and reasons for admissions to Wisconsin pediatric intensive care units (PICU) during the advent of the COVID-19 pandemic, and we hypothesized that the rates of total, scheduled, and respiratory viral admissions were lower during the first calendar year of the pandemic than would have been predicted by historical admission data. Such findings would reflect important changes in PICU utilization paradigms during the pandemic. There are no descriptions of PICU admission changes in a single American state during the pandemic.

Methods: We compared all Wisconsin PICU admissions during the COVID-19 pandemic in 2020 (the study epoch) to admissions in seasonally matched, growth-adjusted “no-COVID-19” projections generated by time series analysis of all Wisconsin PICU admissions in the previous 5 years (the control epoch).

Results: We identified 27,425 PICU admissions with 294,577 associated diagnoses in the study and control epochs. Total admissions were 60 ± 9 week⁻¹ in the study epoch versus 103 ± 4 projected (RR 0.63; 95% CI, 0.59-0.68; $P < 0.001$). Scheduled admissions were 17 ± 6 week⁻¹ in the study epoch versus 28 ± 3 projected (RR 0.61; 95% CI, 0.55-0.67; $P < 0.001$). Respiratory viral admissions were 8 ± 5 week⁻¹ in the study epoch versus 19 ± 9 projected (RR 0.40; 95% CI, 0.33-0.48; $P < 0.001$). Some admission categories experienced dramatic declines (eg, respiratory/ear, nose, throat), while others experienced less decline (eg, injury/poisoning/adverse effects) or no significant change (eg, diabetic ketoacidosis). Except cases of COVID-19, no category had significantly increased weekly admissions. There were 104 admissions associated with COVID-19 diagnoses in 2020, 4.3% of the study epoch admissions.

Conclusions: We describe PICU admission changes in the first calendar year of COVID-19, informing health care staffing and service planning, as well as decisions regarding strategies to combat the evolving pandemic.

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BACKGROUND

The COVID-19 pandemic disrupted health care in unanticipated ways.¹ While some hospitals were tragically overwhelmed by an influx of patients outstripping resources,² other settings encountered reductions in health care service demands.³⁻⁷ Pediatrics enterprises, for example, have seen reduced care demands from outpatient visits⁸⁻¹¹ to critical care hospitalizations.¹²⁻¹⁶

There are no descriptions of PICU admission changes in a single American state (with defined territory, demographics, and COVID-19 population data) during the pandemic. Wisconsin presents a unique opportunity to study the effects of the COVID-19 pandemic and response on pediatric critical care admissions. Five pediatric intensive care units (PICU) serve Wisconsin’s population of approximately 5.8 million, with an under-18 population of 1.3 million.¹⁷ All 5 PICUs participate in the Wisconsin Regional Pediatric Critical Care Consortium, formed in 2015 to foster research, quality improvement, and professional collaboration among the PICUs in the state and region. March 25, 2020, was the first day of Wisconsin’s “Safer at Home” emergency executive order in response to COVID-19,¹⁸ and our perception was that PICU admissions starkly declined thence and remained reduced throughout the calendar year.

We designed this study to determine

if the 2020 springtime decline in PICU admissions was different from the usual seasonal decline and if certain types of PICU admissions were responsible for any identified changes. We hypothesized that the total rate of PICU admissions, the rate of scheduled admissions, and the rate of respiratory viral admissions would be lower during the COVID-19 pandemic in 2020 than in seasonally matched, growth-adjusted “no-COVID-19” projections modeled from admission rates in the previous 5 years. We also hypothesized that rates of other types of PICU admissions would be higher in some categories and lower in others during the COVID-19 pandemic in 2020 compared to no-COVID-19 projections, reflecting broad changes in the reasons for admissions to Wisconsin PICUs.

METHODS

In this retrospective cohort study, all 5 Wisconsin PICUs contributed deidentified clinical data comparing admissions in the 40-week study epoch (March 25, 2020 through December 31, 2020) to those projected from the preceding 5 years’ data (March 25, 2015 through March 24, 2020, the control epoch).

Each PICU obtained its data from the Virtual Pediatric Systems database (Virtual Pediatric Systems [VPS], LLC, Los Angeles, California). The VPS is a clinical database dedicated to standardized data sharing among PICUs and is used to track outcomes, measure quality, and conduct research.¹⁹ The VPS neither endorsed nor restricted our interpretation of data. The Marshfield Clinic Institutional Review Board determined the study was exempt human-subjects research.

Our inclusion and exclusion criteria were the same as those for inclusion in VPS; briefly, we included all PICU admissions of children and adults but excluded patients who were transiently present in the PICU (eg, for procedures) without an admission order. For each PICU admission, we extracted the following data: approximate admission date (within 1 day of the actual admission date), demographics, all admission-associated diagnoses (both primary and secondary), the VPS category associated with each diagnosis, scheduled or unscheduled status, and trauma or non-trauma status.

Mean weekly admission rates with standard deviations from the study epoch were compared to those projected from the control epoch using rate ratios with 95% confidence intervals. To generate the counterfactual no-COVID-19 admission projections, we performed time series analysis with a quasi-Poisson model regressed on time, a study epoch indicator, and a first-order autoregressive lag with harmonic terms. The resultant no-COVID-19 projections may be conceived as a business-as-usual scenario (ie, an estimate of what PICU admission rates would have been if the COVID-19 pandemic had never occurred). For a more conservative comparison, we also present admission rates from record-low comparator periods, which are 40-week spans in the previous 5 years with the lowest admission rate in each category.

Table 1. Cohort Demographics

Demographic Characteristic	Control Epoch 3/25/15 – 3/24/20	Study Epoch 3/25/20 – 12/31/20
Total admissions	24,980	2,445
Total diagnoses	266,528	28,049
Median age	4.5	6.6
Sex		
Female	11,000 (44%)	1,127 (46%)
Male	13,980 (56%)	1,318 (54%)
Race/ethnicity		
White	15,276 (61%)	1,501 (61%)
Black or African American	4,416 (18%)	456 (19%)
Hispanic or Latino	1,906 (8%)	232 (9%)
Asian	503 (2%)	61 (2%)
Asian/Indian/Pacific Islander	395 (2%)	0(0%)
American Indian or Alaska Native	362 (1%)	34 (1%)
Native Hawaiian or other Pacific Islander	30 (<1%)	5 (<1%)
Other/Mixed	541 (2%)	61 (2%)
Unspecified	1551 (6%)	95 (4%)

We analyzed admissions *in total* and admissions *by category*, defining the following admission categories: scheduled (vs unscheduled), respiratory viral (vs non), trauma (vs non), primary diagnosis category (eg, respiratory/ear, nose, throat [ENT], neurological, cardiovascular), and whether admissions were associated with a diagnosis of interest, selected a priori (see Appendix: Admission Category Definitions). We chose the diagnoses of interest based on perceived changes in our PICU admission requests and in an effort to objectively evaluate reports in the lay and scientific press with implications for pediatric critical care.^{8,20-24} Apart from respiratory viral infections, the diagnoses of interest were diabetic ketoacidosis (DKA), self-harm and suicide, accidental ingestions, child abuse, and asthma exacerbations. Due to the number of admission categories reviewed, we considered $P \leq 0.01$ significant for all analyses.

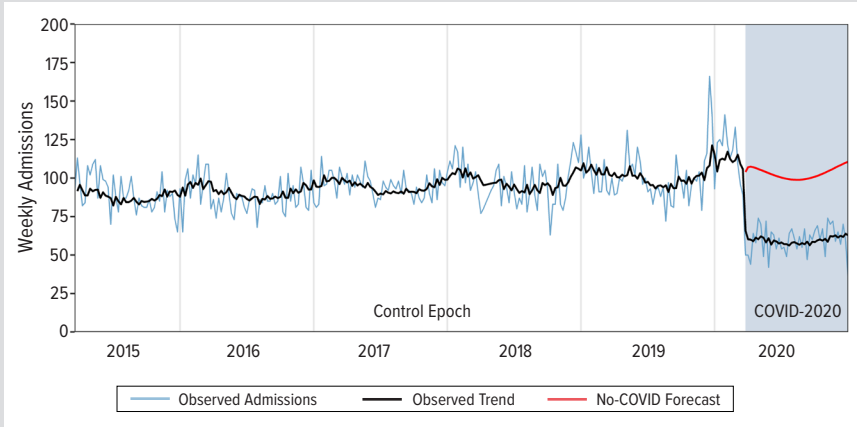
Finally, we also present the total number of Wisconsin PICU admissions with a diagnosis of COVID-19 in 2020. All analyses were completed in R version 4.0.2 using the following packages: readr, lubridate, grid, projection, tsModel, lmtree, Epi, splines, vcd, ggplot2, and RColorBrewer.²⁵

RESULTS

There were 27,425 PICU admissions in Wisconsin with 294,577 associated diagnoses from March 25, 2015, through December 31, 2020 (Table 1). Despite an under-18 population decline of 0.4% annually,²⁶ PICU admissions increased by 2.7% annually during the 5-year control epoch.

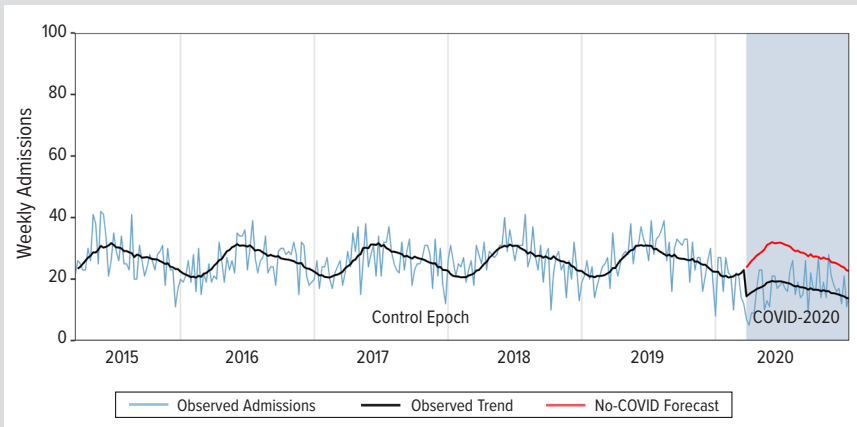
During the study epoch of COVID-19 in 2020, there were 60 ± 9 *total* admissions per week compared to 103 ± 4 projected (RR 0.63; 95% CI, 0.59-0.68; $P < 0.001$). There were 17 ± 6 *scheduled* admissions per week compared to 28 ± 3 projected (RR 0.61; 95% CI, 0.55-0.67; $P < 0.001$), and there were 8 ± 5 *respiratory viral* admissions per week compared to 19 ± 9 projected (RR 0.40;

Figure 1. Total Weekly Admissions Before and During the Pandemic With No-COVID-19 Projection Counterfactual Comparison



Total weekly admissions (blue) with trend (black) are compared to a projected no-COVID-19 admission trend from a quasi-Poisson model of weekly admissions regressed on an indicator for the COVID-19 pandemic, annual growth, a 1-week lag, and harmonic terms to account for seasonality. The estimated rate ratio for the study epoch was 0.63 (95% CI, 0.59-0.68; $P < 0.001$), meaning that admissions during the study epoch were 37% lower than expected after accounting for annual growth and seasonality.

Figure 2. Weekly Scheduled Admissions Before and During the Pandemic With No-COVID-19 Projection Counterfactual Comparison



Weekly scheduled admissions (blue) with trend (black) are compared to a projected no-COVID-19 admission trend from a quasi-Poisson model of admissions regressed on an indicator for the COVID-19 pandemic, a 1-week lag, and harmonic terms to account for seasonality. The estimated rate ratio for the study epoch was 0.61 (95% CI, 0.55-0.67; $P < 0.001$) meaning that scheduled admissions during the study epoch were 39% lower than expected after accounting for seasonality.

95% CI, 0.33-0.48; $P < 0.001$). For each category of interest in our primary hypothesis (total admissions, scheduled admissions, and respiratory viral admissions) the model-projected trend mirrored observed admissions during the control epoch, confirming model validity, but the projected trend significantly exceeded observed admissions during the study epoch (Figures 1-3).

Among other subcategories, admission rates associated with particular respiratory viruses are presented; there were precipitous reductions in respiratory syncytial virus, adenovirus, human metapneumovirus, enterovirus, and nonpandemic coronavirus admissions. The trauma admission rate was 4 ± 2 during the study

epoch—less than 6 ± 1 in the projection (RR 0.73; 95% CI, 0.63-0.86; $P < 0.001$) but equal to the admission rate during the record low comparator period. With the exception of COVID-19 cases, admissions with a diagnosis of interest were also less frequent than projected. The significance threshold was met for asthma exacerbation admissions (1 ± 1 vs 5 ± 1 ; RR 0.28; 95% CI, 0.20-0.40; $P < 0.001$) and suicide and self-harm admissions (2 ± 2 vs 4 ± 1 ; RR 0.59; 95% CI, 0.46-0.77; $P < 0.001$) (Table 2).

When we considered admissions according to the 23 mutually exclusive VPS diagnostic categories based largely on body systems, the greatest reductions between observed and projected admissions occurred in respiratory/ENT (12 ± 3 vs 30 ± 5 ; RR 0.41; 95% CI, 0.35-0.47; $P < 0.001$), neurologic (7 ± 3 vs 12 ± 0 ; RR 0.60; 95% CI, 0.51-0.70; $P < 0.001$), and cardiovascular (10 ± 4 vs 15 ± 1 ; RR 0.67; 95% CI, 0.58-0.76; $P < 0.001$) admissions (Table 2).

Finally, there were 104 PICU admissions associated with COVID-19 diagnoses in Wisconsin in 2020. The admissions were of children in 96 cases and of adults age greater than 17 years in the remaining 8 cases. All of the COVID-19 admissions occurred during the 40-week study epoch, comprising 4.3% of the PICU admissions during that time period. COVID-19 was the primary diagnosis in 36 of the 104 cases.

DISCUSSION

The study reveals how PICU utilization changed in Wisconsin during the COVID-19 pandemic in 2020. We identify a 37% decline overall in PICU admissions compared to the no-COVID-19 projection, consistent with our first hypothesis. The 37% reduction in total PICU admissions is greater than the 32% admission reduction reported amongst a larger group of American PICUs also contributing to VPS; however, rather than employing time series analysis, that study directly compared quarter 2 of 2020 to quarters 2 of 2017, 2018, and 2019.¹²

We aimed to identify if changes in certain categories of PICU utilization were responsible for the overall admission reduction. Scheduled admissions, respiratory viral admissions, and

trauma admissions contained nearly distinct groups of critically ill children and accounted for 56% of the total decline in admissions. If considering admissions according to VPS primary diagnosis category, the reduction in respiratory/ENT admissions alone accounted for 42% of the total admission decline. But PICU admissions were reduced almost across the board; with the exception of COVID-19 admissions, every admission category exhibited either a reduction in observed versus projected admissions or no significant admission frequency change.

Admissions of patients with COVID-19, DKA, suicide and self-harm, and asthma warrant additional discussion.

COVID-19 Admissions

We report 96 out of a population of 1.3 million children required PICU admission with a COVID-19 diagnosis in 2020. During the same time, there were 58,022 confirmed cases of COVID-19 among children in Wisconsin.²⁷ We do not know if the primary-secondary designation on the COVID-19 diagnoses reliably distinguishes true cases of COVID-19 disease from incidental findings of SARS-CoV-2-positive nasal swabs. Nor could we differentiate multisystem inflammatory syndrome in children (MIS-C) from non-MIS-C SARS-CoV-2-related critical illness, since the diagnostic code for MIS-C was not available until 2021. In any case, the low incidence of PICU admissions with COVID-19 diagnoses emphasizes the low burden of critical COVID-19 disease among children during the study epoch.

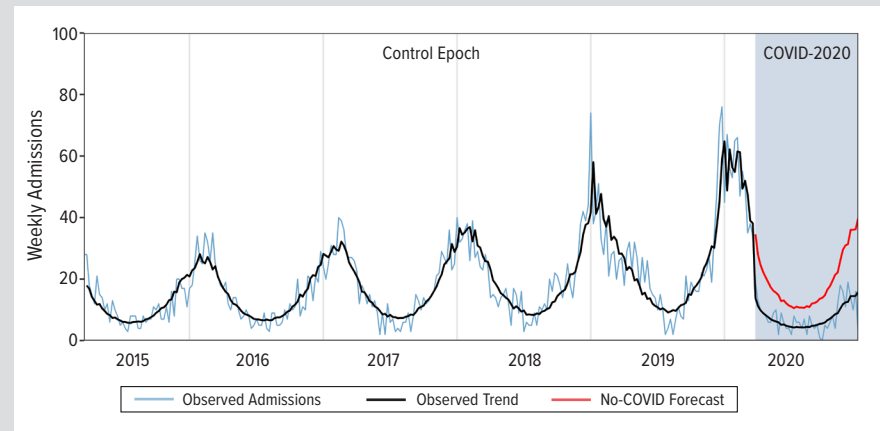
Diabetic Ketoacidosis Admissions

The trend toward decreased PICU admissions with DKA in Wisconsin differed from the increase reported in the other analysis of American PICU admissions,¹² but we would not have identified a reduction if we had not accounted for an 8.2% annual growth in DKA PICU admissions during the control epoch. Nonetheless, there are several reports of links between DKA and COVID-19, and an open international registry exists.^{22,28-30}

Suicide and Self-Harm Admissions

Despite reports of increased positive results on adolescent suicide risk screens³¹ and emergency department visits and hospitalizations for pediatric mental health concerns,³²⁻³⁸ PICU admissions for suicide and self-harm in Wisconsin were approximately the same during the study epoch as during the record low comparator period and 41% less frequent than anticipated by the no-COVID-19 projection. These findings are consistent with decreased calls to poison control centers resulting in hospitaliza-

Figure 3. Weekly Respiratory Viral Admissions Before and During the Pandemic With No-COVID-19 Projection Counterfactual Comparison



Weekly respiratory viral admissions (blue) with trend (black) are compared to a projected no-COVID-19 admission trend from a quasi-Poisson model of weekly admissions regressed on an indicator for the COVID-19 pandemic, annual growth, a 1-week lag, and harmonic terms to account for seasonality. The estimated rate ratio for the study epoch was 0.40 (95% CI, 0.33-0.48, $P < 0.001$) meaning that respiratory viral admissions during the study epoch were 60% lower than expected after accounting for annual growth and seasonality.

tion during COVID-19.³⁹ The other VPS study to evaluate mental health diagnoses in PICU admissions during COVID-19 reported decreased attempted suicide but increased poisoning/ingestions.¹² Further research could identify if mental health presentations to PICUs (eg, life-threatening ingestions) increased after this study epoch ended in December 2020, when stressors associated with the COVID-19 pandemic and societal response to it were ongoing. Alternatively, increased pediatric mental health complaints associated with the pandemic may not correspond with increased PICU utilization.

Asthma Admissions

Initially, it would have been reasonable to hypothesize there would be increased PICU admissions with asthma during COVID-19;⁴⁰ however, the opposite proved true. In fact, patients with asthma and COVID-19 fared as well as those without asthma.⁴¹ Wisconsin PICU admissions associated with asthma were significantly reduced during the study epoch, consistent with reports that pediatric asthma exacerbations requiring treatment with systemic steroids decreased.⁸

Study Strengths

A strength of this study was our ability to account for chronological growth or decay in admission frequency during the control epoch. In addition, seasonal variability in health care does not respect calendar designations, so comparing the incidence of a seasonal illness in the same week of 2 different years is often inappropriate. We accounted for both of these confounders by measuring and adjusting for growth or decay in PICU utilization over the preceding 5 years, using a relatively long—40-week—study epoch, and selecting historical control periods based on the elapsed time between the preceding admission rate nadir and day 1 of each

Table 2. Weekly Admission Rates by Category

Category	Comparison of Projection and Observed					
	Record Low	No-COVID-19 Projection	COVID-19 Observed	Rate Ratio	% Change	P value
Total admissions	86±9	103±4	60±9	0.63 (0.59–0.68)	-37%	<0.001
Scheduled admissions	23±5	28±3	17±6	0.61 (0.55–0.67)	-39%	<0.001
Respiratory viral admissions	11±5	19±9	8±5	0.40 (0.33–0.48)	-60%	<0.001
Influenza	0.2±0.5	1±1	0.02±0.16	0.02 (0.00–0.42)	-98%	0.012
Rhinovirus	0	0.1±0.0	0	—	—	—
Nonpandemic coronavirus	0	0.5±0.0	0.02±0.16	0.05 (0.01–0.47)	-95%	0.009
Adenovirus	0.5±0.7	1.0±0.0	0.5±0.8	0.45 (0.26–0.78)	-55%	0.005
Human metapneumovirus	0.0±0.2	1.0±1.0	0.2±0.8	0.21 (0.11–0.42)	-79%	<0.001
Respiratory syncytial virus	1±2	3±5	0.3±1.1	0.08 (0.04–0.18)	-92%	<0.001
Enterovirus	0.1±0.3	1.6±0.0	0.7±0.8	0.47 (0.29–0.77)	-53%	0.003
Parainfluenza	0.2±0.5	1.1±1.0	0.0±0.2	0.02 (0.00–0.42)	-98%	0.012
Trauma admissions	4±2	6±1	4±2	0.73 (0.63–0.86)	-27%	<0.001
Cardiovascular	13±3	15±1	10±4	0.67 (0.58–0.76)	-33%	<0.001
Dermatologic	0.1±0.3	0.3±0	0.0±0.2	0.16 (0.04–0.67)	-84%	0.014
Endocrine	3±2	5±0	4±2	0.78 (0.64–0.95)	-22%	0.015
Factors influencing health	0.0±0.2	0.3±0.0	0.3±0.6	1.05 (0.61–1.81)	5%	0.865
Gastrointestinal	2±1	2±0	2±1	0.96 (0.72–1.27)	-4%	0.766
Genetic	1±1	1±0	1±1	0.64 (0.45–0.91)	-36%	0.013
Gynecologic	0	0.0±0.0	0.0±0.2	1.60 (0.13–13.95)	60%	0.671
Hematologic	0.4±0.7	0.5±0.0	0.6±0.9	1.20 (0.79–1.83)	20%	0.394
Immunologic	0	0.0±0.0	0.0±0.2	1.06 (0.13–8.45)	6%	0.957
Infectious	4±2	7±1	5±3	0.62 (0.50–0.78)	-38%	<0.001
Injury/poisoning/adverse effects	11±3	12±1	8±3	0.73 (0.65–0.82)	-27%	<0.001
Metabolic	0.8±0.7	1.0±0.0	0.6±0.8	0.66 (0.45–0.99)	-34%	0.045
Neurologic	9±3	12±0	7±3	0.60 (0.51–0.70)	-40%	<0.001
Newborn/perinatal	0.2±0.5	0.3±0.0	0.2±0.5	0.86 (0.44–1.68)	-14%	0.654
Oncologic	2±2	3±0	2±1	0.74 (0.60–0.92)	-26%	0.008
Ophthalmologic	0	0.1±0.0	0	—	—	—
Orthopedic	1±1	1±0	0	0.68 (0.43–1.07)	-32%	0.094
Psychiatric	0.1±0.4	0.6±0.0	0.4±0.7	0.61 (0.31–1.19)	-39%	0.151
Renal/genitourinary	0.7±0.8	1.2±0.0	0.9±1.0	0.73 (0.50–1.06)	-27%	0.100
Respiratory and respiratory/ear, nose, throat	23±6	30±5	12±3	0.41 (0.35–0.47)	-59%	<0.001
Rheumatologic	0.1±0.3	0.2±0.0	0.4±0.8	2.16 (1.12–4.15)	216%	0.022
Symptoms	1±1	2±0	2±2	1.09 (0.88–1.36)	9%	0.443
Transplant	0.1±0.3	0.3±0.0	0.3±0.5	0.86 (0.46–1.61)	-14%	0.644
Diabetic ketoacidosis	3±2	6±0	4±2	0.78 (0.64–0.95)	-22%	0.014
Suicide and self-harm	2±2	4±1	2±2	0.59 (0.46–0.77)	-41%	<0.001
Accidental ingestions	1±1	2±0	1±1	0.69 (0.48–1.00)	-31%	0.053
Child abuse	0.1±0.3	0.3±0.0	0.2±0.4	0.72 (0.37–1.41)	-28%	0.335
Asthma exacerbation	4±2	5±1	1±1	0.28 (0.20–0.40)	-72%	<0.001

We compared admissions in the 40-week study epoch (3/25/2020–12/31/2020), to those projected from the preceding 5 years' data (3/25/2015–3/24/2020, the control epoch) using mean weekly admission rates with standard deviations and rate ratios with 95% CIs. For context, we also present admission rates in record-low comparator periods, the 40-week spans in the previous 5 years with the lowest admission rate in each category.

period rather than directly comparing admission frequencies in the same weeks of different years.

Another strength of the study is that we obtained all primary and secondary diagnoses associated with all PICU admissions, thereby gathering the most complete data regarding the reason for each admission. The analysis of secondary diagnoses corrected for any possible inconsistency in how the primary and secondary diagnoses may have been designated from site to site.

Finally, associations identified in retrospective studies do not

necessarily imply causation, but despite being retrospective, our study does provide some insight into why PICU admissions declined. The reduction in admissions was not limited to categories such as respiratory admissions or scheduled admissions; in fact, these categories only account for about half of the total decline, suggesting one should reject assumptions that attribute admission reductions to only 1 component of the COVID-19 pandemic or response (eg, stay-at-home orders reducing community viral circulation or cancellation of nonurgent hospital procedures).

Limitations

Though this was a multicenter study, it reflects the experience of 1 state. More than half the admissions were in 1 PICU. Generalizability is limited to areas and populations sufficiently similar to Wisconsin. As noted previously, further research with a longer study epoch might identify important PICU admission alterations associated with the COVID-19 pandemic and response that were not evident before the end of 2020. Finally, we requested pediatric mortality data from the Wisconsin Department of Vital Statistics, but at the time of this writing such contextual data was not available.

CONCLUSIONS

At the onset of the COVID-19 pandemic, we might have predicted increased PICU admissions in 2020, but total, scheduled, and respiratory viral admissions in Wisconsin declined by 37%, 39%, and 60%, respectively. Material and human resources usually designated for pediatric intensive care were available for dismissal or deployment elsewhere.

This retrospective study of PICU admissions during the first calendar year of the COVID-19 pandemic yielded both foreseeable and unexpected results. Only half the reduction in total admissions was from predictable categories, such as scheduled and respiratory viral admissions. Unexpected findings emphasize the importance of objectively observing paradigm shifts, identifying inconsistencies between assumptions and observations, and adapting treatment and mitigation efforts to new discoveries as the COVID-19 pandemic evolves in the years to come.

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