



Emergency pediatric radiology imaging trends for non-COVID-19-related illnesses through different stages of the pandemic

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Abstract

Purpose To evaluate how the COVID-19 pandemic affected the imaging utilization patterns for non-COVID-19-related illness in a pediatric emergency department (ED).

Methods We retrospectively reviewed radiology reports for ultrasound, CT, MRI, and fluoroscopy studies performed at a pediatric ED in April from 2017 to 2021, excluding studies for respiratory symptoms and trauma. Radiology reports and medical records were reviewed to determine if patients had a positive radiology diagnosis, the type of diagnosis, and whether it required hospital admission. Results from during the pandemic were compared to predicted rates based on pre-pandemic years.

Results A total of 2198 imaging studies were included. During the COVID-19 pandemic, fewer ED imaging studies were performed compared to predicted. The decrease was greater in April 2020 (RR = 0.56, $p < 0.001$) than in April 2021 (RR = 0.80, $p = 0.038$). The odds of positive diagnosis was higher during the pandemic than before, and higher in 2020 (OR 2.53, $p < 0.001$) than in 2021 (OR 1.38, $p = 0.008$). The expected numbers of positive diagnoses and hospital admittances remained within the predicted range during the pandemic ($p = 0.505$ – 0.873).

Conclusions Although imaging volumes decreased during the studied months of the pandemic, the number of positive findings was unchanged compared to prior years. No differences were demonstrated in the percentage of patients admitted to the hospital with positive imaging findings. This suggests that, at our institution, the pandemic did not lead to a substantial number of missed diagnoses or severely delay the diagnosis of non-COVID-related conditions. While still lower than expected, imaging volumes increased in April 2021 suggesting a return towards baseline patient behavior as the pandemic conditions improved.

Keywords COVID-19 · Pediatric · Emergency Department, Utilization

Introduction

The novel coronavirus disease 2019 (COVID-19) was declared a pandemic on March 11, 2020, by the World Health Organization. Soon after, the United States (US) declared a national emergency. To curb pandemic spread, many states enforced mandatory stay-at-home orders in March 2020, which limited gatherings and temporarily closed non-essential businesses and organizations [1]. Additionally, the Centers for Disease Control (CDC) recommended that healthcare systems prioritize urgent visits and delay elective care [2]. Many healthcare facilities were urged to reallocate resources in preparation for the impending rise in hospital admissions related to COVID-19, and also to encourage patients to use telehealth services instead of seeking in-person medical care

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for preventative and non-emergent care [3]. Subsequently, the volume of patients seeking emergency medical care in the US decreased dramatically during the early stages of the pandemic, with the largest decreases observed in April 2020, in the most severely impacted areas [4].

Several adult and pediatric studies in the US and similarly affected European countries have shown that the decrease in patient volume was associated with an unexpected decrease in the number of patients presenting to the emergency department (ED) with non-COVID-associated emergencies including acute coronary syndromes, strokes, and appendicitis [5–8]. Of the adult patients who were diagnosed with non-COVID emergencies, many exhibited more acute presentations and increased complications, such as gastrointestinal perforations, septicemia, and increased hospital mortality after cardiovascular emergencies [9–11]. These worrisome trends suggest that many adult patients with serious medical conditions either delayed medical care or did not seek appropriate medical attention at all. A small number of studies raised concerns for similar trends in the pediatric population [12, 13]. The objective of this study is to further explore this question by evaluating the effect of the COVID-19 pandemic on pediatric emergency imaging for non-COVID-related indications. In it, we evaluate the number of imaging studies performed, as well as the types and severity of radiologic findings during two different phases of the COVID-19 pandemic: a 1-month period in the first wave of the pandemic, with stay-at-home orders in place, and a 1-month period, 1 year later, during the 3rd wave of the pandemic, after stay-at-home orders had been lifted. We compare these months to the same month in years preceding the pandemic.

Methods

The study was performed at a single, urban, academic children's hospital with over 400 beds. The institutional review board granted an exemption, and written patient or guardian consent was waived. We retrospectively reviewed all radiology reports for advanced imaging studies (ultrasound, computed tomography (CT), magnetic resonance (MR), and fluoroscopy) performed on emergency department patients of all ages during the month of April, for the years 2017 through 2021. April 2020 was the first full month of the COVID-19 pandemic, with the most dramatic decrease in the volume of patients seeking emergency medical care [4, 5, 14]. Similarly, at our institution, April 2020 showed the lowest ED patient volume between January 2017 and June 2021, with only 2185 total patients compared to an average volume of about 5000 patients per month over the 3 years preceding the pandemic. We included all internally generated reports for studies performed at our institution

and those performed at outside institutions for which a second opinion consultation report was requested by the ED staff. These studies were identified by searching radiology reports for the included dates and modalities using Nuance® PowerScribe® 360 Reporting and Montage® Search and Analytics tools.

The clinical indications for the imaging studies were reviewed. We excluded imaging studies requested for evaluation of airway or respiratory symptoms, because these might coincide with studies evaluating patients for COVID-19. We also excluded imaging studies requested for trauma evaluation to avoid the confounding effect of decreased trauma rates associated with stay-at-home orders [15–17]. Radiographs were excluded because most chest and extremity radiographs in our ED are performed to evaluate for respiratory symptoms or trauma.

We reviewed individual radiology reports and designated each study as either a positive diagnosis, based on abnormal imaging findings that would account for the patient's presenting symptoms, or a negative diagnosis. If a patient underwent multiple imaging studies to evaluate for the same diagnosis, only one study was counted, with priority given to a positive exam, and the other exams were excluded. However, if a patient had two imaging studies for different indications (involving different anatomic locations), both studies were included. Positive studies were further categorized as those that required hospital admission and those that did not. All positive studies were categorized by diagnosis type (Table 1). Acute appendicitis (AA) was subcategorized separately because it is a relatively common, time-sensitive diagnosis where delayed presentation and treatment could result in increased complications or worse outcomes [18].

Statistical analysis

The study's main outcome variables were imaging frequency, diagnosis, and admission, all potentially depending on year. Frequency data was fit by Poisson exponential models to estimate rates (mean frequency per year), and binary data was fit by binomial logistic models to estimate odds and probabilities of events [19]. Comparisons were via ratios of rates (RR) for Poisson models and via ratios of odds (OR) for binomial models. Statistical significance for testing the equality of rates and odds was at the 5% level.

Regression-type models (treating year numerically as 0–4 for years 2017–2021) were used to predict 2020 and 2021 rates and odds based on 2017–2019 data using SAS's NLMIXED (nonlinear mixed models) procedure [20]. These predictions were compared to actual observed data for 2020 or 2021 based on a comparison of two independent rates or odds. Regression models for all outcomes except diagnosis odds included a predictor for year. For diagnosis odds, the Akaike information criterion (AIC) favored the simpler

Table 1 Diagnosis categories and rates

Category	Types of diagnoses included	Number of cases per year				
		2021	2020	2019	2018	2017
Gastrointestinal illnesses (GI)	Intussusception, bowel obstruction, inflammatory or infectious bowel disease, malrotation, esophageal foreign body, acute cholecystitis, pancreatitis, intra-abdominal abscess	43	51	39	32	19
	Acute appendicitis (AA)	22	33	26	18	12
Soft tissue abnormalities (ST)	Osteomyelitis, myositis, synovitis, joint effusion, cellulitis, abscess	15	18	11	13	11
Head and neck infections (HN)	Cervical lymphadenitis, sialoadenitis, retropharyngeal and parapharyngeal infections, orbital infections, acute sinusitis, mastoiditis, otitis, thyroiditis, odontogenic infections	13	11	19	14	21
Neurologic abnormalities (N)	Ventriculomegaly, intracranial hemorrhage, stroke, cerebritis, cerebral edema, optic neuritis, spinal cord infections/inflammation	31	7	11	8	14
Oncologic diagnoses (ON)	New diagnosis and complications of existing diagnosis	6	7	3	6	5
Hematologic abnormalities (H)	Deep venous thrombosis, pulmonary embolism, vascular and lymphatic malformations, other bleeding disorder	2	3	5	0	0
Genitourinary diagnoses (GU)	Epididymitis, orchitis, torsed appendage, renal stones, pyelonephritis, salpingitis, tubo-ovarian abscess, ectopic pregnancy, gonadal torsion	24	30	16	14	15
Total		134	127	104	87	85

model (AIC = 21) to the model including year (AIC = 23) [21].

Results

A total of 2198 imaging studies were included in the analysis. The distribution of frequencies over diagnosis categories is listed in Table 1. Gastrointestinal disease was the most common diagnosis category in aggregate over 2017–2021 and appendicitis was the most common individual diagnosis for each of the 5 years. Rates and odds for 2017–2021 are summarized in Table 2.

We predicted increased imaging rates for 2020 and 2021 based on the observed trend of rising imaging rates from 2017 to 2019. Imaging rates in 2020 and 2021 were both

lower than predicted, with a more pronounced decrease in 2020 (RR = 324/574 = 0.56, $p < 0.001$) than in 2021 (RR = 515/647 = 0.80, $p = 0.038$) (Fig. 1).

Compared to predictions based on increasing trends over 2017–2019, the number of patients with a positive diagnosis on an ED imaging exam did not significantly change in either 2020 (RR = 1.13, $p = 0.505$) or 2021 (RR = 1.07, $p = 0.774$) (Fig. 2A). Because imaging rates were lower than predicted, the odds of a positive diagnosis were significantly higher than predicted in both 2020 (OR = 0.64/0.25 = 2.53, $p < 0.001$) and 2021 (OR = 0.35/0.25 = 1.38, $p = 0.008$) (Fig. 2B).

Compared to predictions based on 2017–2019 data, the change in admission rates was not significant in either 2020 (RR 83/80 = 1.04, $p = 0.873$) or 2021 (RR = 85/97 = 0.88, $p = 0.668$) (Fig. 3A). The change in the odds of admission

Table 2 Rates and odds for 2017–2021

Year	Imaging rate	Diagnosis rate	Admission rate	Diagnosis odds	Admission odds
2017	395	85	46	0.27	1.18
2018	460	87	53	0.23	1.56
2019	504	104	67	0.26	1.81
2020	324	127	83	0.64	1.89
2021	515	134	85	0.35	1.73
Pred (2020) ^a	574	113	80	0.25	2.28
Pred (2021) ^a	647	125	97	0.25	2.83
2020 vs Pred	RR = 0.56 $p < 0.001$	RR = 1.13 $p = 0.505$	RR = 1.04 $p = 0.873$	OR = 2.53 $p < 0.001$	OR = 0.83 $p = 0.604$
2021 vs Pred	RR = 0.80 $p = 0.038$	RR = 1.07 $p = 0.774$	RR = 0.88 $p = 0.668$	OR = 1.38 $p = 0.008$	OR = 0.61 $p = 0.322$

^aPrediction of 2020 or 2021 based on 2017–2019 data: models depend on year for imaging rate, diagnosis rate, admission rate, and admission odds, and do not depend on year for diagnosis odds

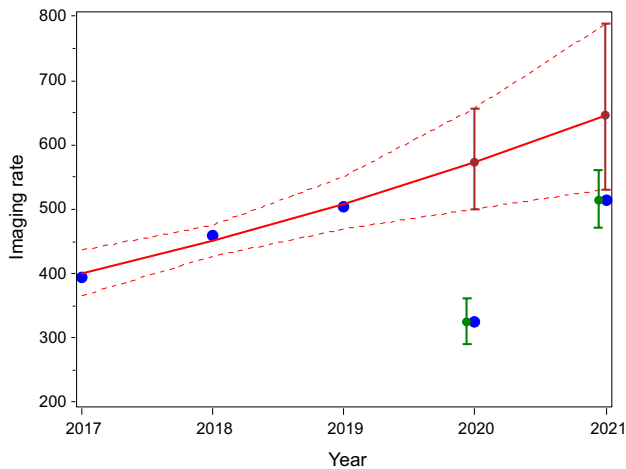


Fig. 1 Observed versus predicted imaging rates. Observed rates for 2017–2021 are plotted in blue. Estimates and predictions for 2017–2021 based on 2017–2019 data are indicated by the red solid line with red dashed lines for 95% CIs. Observed rates in 2020 and 2021 (green dots with green lines for 95% CIs) were lower than predicted (brown dots with brown lines for 95% CIs)

was also not significantly different from predicted in either year (2020: $OR = 1.89/2.28 = 0.83$, $p = 0.604$; 2021: $OR = 1.73/2.83 = 0.61$, $p = 0.322$) (Fig. 3B).

Discussion

This study evaluates two different periods of time during the COVID-19 pandemic. April 2020 was the first full month of the pandemic and coincided with the first wave in the state of Massachusetts with 56,573 statewide cases of COVID-19 diagnosed in April 2020, compared to 7697 cases 1 month earlier. April 2020 also saw the greatest number of deaths from COVID-19 in Massachusetts compared to any other month of the pandemic at 3594 [22]. April 2021 coincided with a third wave of the pandemic, with 49,082 cases of COVID-19 diagnosed in April, and similar numbers 1 month earlier [22]. Although the monthly new caseload of infections was not substantially lower than 1 year earlier, effective vaccines for COVID-19 had become available and by April 30, 2020, approximately 35% of residents in Massachusetts were fully vaccinated and 56% had received at least one dose [23]. The death toll of the virus had also decreased with April 2021 seeing 480 deaths from COVID-19 statewide [22]. Because of improving public health metrics, by March 22, 2021, Massachusetts entered the final phase of the statewide reopening plan to gradually allow businesses, services, and activities to return to normal [24].

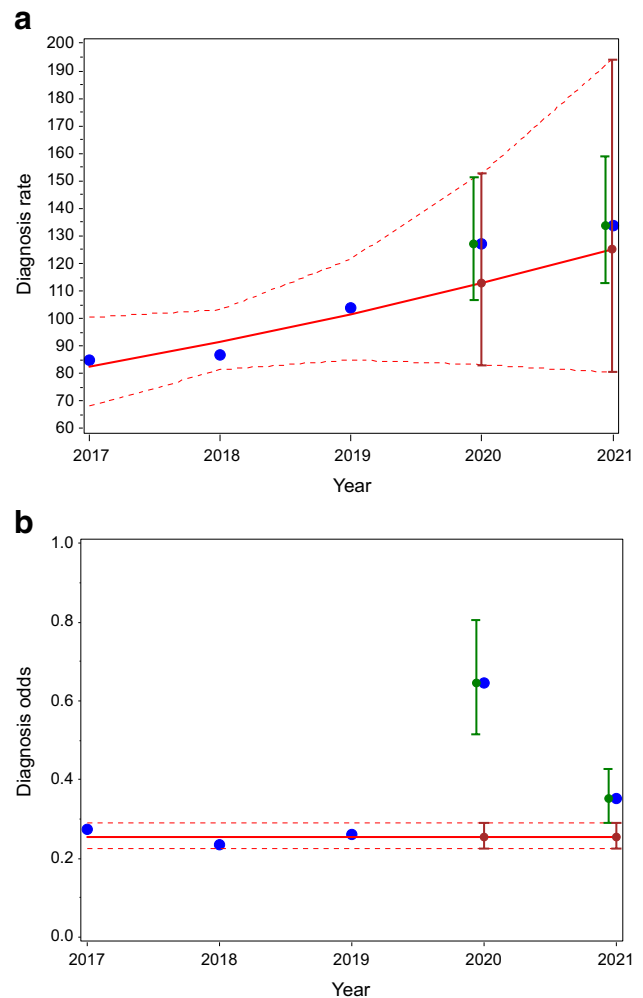


Fig. 2 **A** Observed versus predicted positive diagnosis rate. The observed rates for all years are plotted in blue. The red solid and dashed lines indicate estimated predictions based on 2017–2019 data with 95% confidence interval for the 2020 and 2021 rates. The observed rates in 2020 and 2021 (green dot, with green lines indicating confidence interval) were within predicted rates (brown dot and lines). **B** Observed versus predicted positive diagnosis odds. The observed odds for all years are plotted in blue. Estimates and predictions for 2017–2021 based on 2017–2019 data are indicated by the red solid line with red dashed lines for 95% CIs. The observed positive diagnosis odds in 2020 and 2021 (green dot, with green lines indicating confidence interval) were higher than expected (brown dot and lines for 95% CIs)

Imaging volumes

In the years prior to the pandemic, rates of advanced imaging increased at our institution, consistent with published trends across other pediatric emergency departments [25]. During the pandemic, imaging volumes for our pediatric ED decreased significantly, particularly when compared to predicted volumes based on increasing trends. This finding accords with other studies demonstrating decreases in the

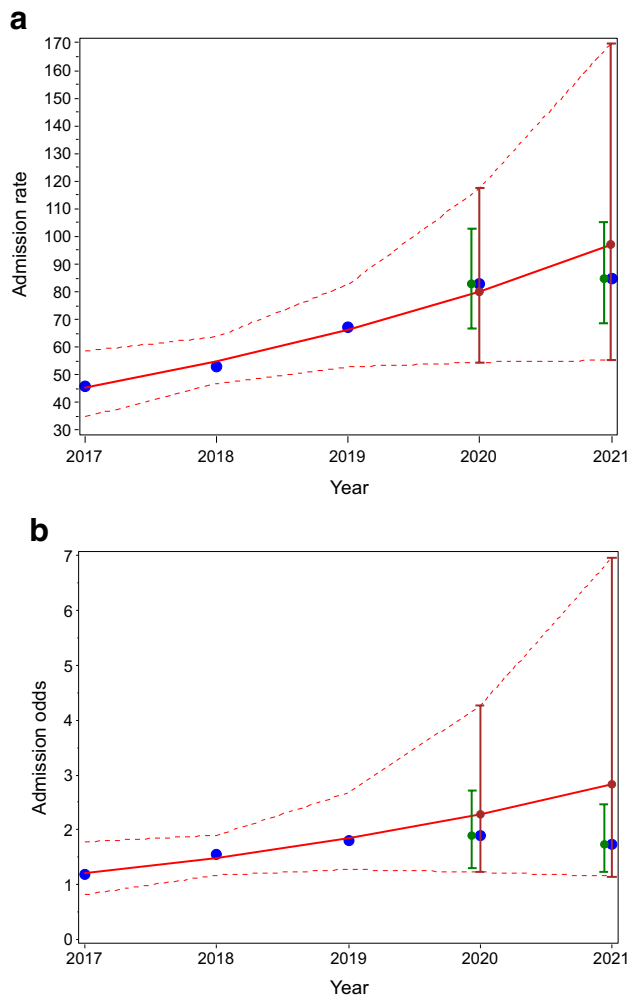


Fig. 3 **A** Observed versus predicted rate of admission for positive diagnoses. The observed rates for all years are plotted in blue. The red solid and dashed lines indicate estimated predictions based on 2017–2019 data with 95% confidence interval for the 2020 and 2021 rates. The observed rates in 2020 and 2021 (green dot, with green lines indicating confidence interval) were within predicted rates (brown dot and lines). **B** Observed versus predicted odds of admission for positive diagnoses. The observed odds for all years are plotted in blue. Estimates and predictions for 2017–2021 based on 2017–2019 data are indicated by the red solid line with red dashed lines for 95% CIs. The observed admission odds in 2020 and 2021 (green dot, with green lines indicating confidence interval) were within the expected range of predicted admission odds (brown dot and lines)

overall number of patients presenting to pediatric EDs during the pandemic, both in the US and abroad [14, 17, 26]. Although associated decreases in imaging studies performed in adult EDs have been reported [27–29], to our knowledge, no studies have evaluated similar trends in pediatric emergency radiology nor have incorporated prediction models to compare changes observed during the pandemic.

The decrease in imaging volumes for pediatric ED patients seen in our study correlated with the overall decreased rate at which children presented to the ED during

the COVID-19 pandemic. As such, several possible explanations exist for the decreased ED imaging volumes we found. Other reports indicate that fear of exposure to COVID-19 was an important potential factor deterring patients from visiting EDs [12]. Decreased ED patient volumes were similarly described during the Severe Acute Respiratory Syndrome (SARS) pandemic in 2003 and the Middle East Respiratory Syndrome (MERS) outbreak in 2015 [30–32]. Additionally, early in the pandemic, governmental and hospital institutional public announcements discouraged patients from visiting EDs for non-urgent medical issues [3]. Before the pandemic, up to 37–60% of pediatric patients arriving to EDs in the US reportedly did so for non-urgent reasons [33]. Both US and international reports indicate that a large decrease in lower acuity visits may account for the majority of decreased ED patient volumes during the pandemic [17, 26, 34]. This suggests that many patients appropriately self-triaged and avoided inappropriate use of the ED. For children, physical distancing and school closures may have decreased incidences of non-COVID-related communicable illnesses, with lower incidences of gastroenteritis, otitis, and other viral diseases compared to previous years [17, 34]. In addition, improved access to telehealth services may have allowed families to avoid some urgent care visits for lower acuity illnesses [14, 35, 36].

The decreased diagnostic imaging volumes in the ED might also have been affected by changes in practice parameters by ED clinicians. One study from an academic pediatric ED reported an association of decreased volumes during the early pandemic with overall shorter time-related patient flow parameters, and fewer patients who left the ED before being seen [14]. This would argue against limited medical resources as a cause for the decrease we observed. One Italian study found a 19% decrease in negative radiology studies ordered for trauma in a pediatric ED during the first wave of the pandemic, compared to the pre-COVID era [34]. The authors attributed this to possibly more appropriate imaging utilization during the pandemic. However, selection could also have been at the patient level, with those presenting to the ED potentially more likely to have positive radiologic findings compared to before the pandemic. In our ED, there are typically low rates of patients who leave without being seen, and staff resources and access to imaging were not limited during the pandemic. Furthermore, there are robust clinical pathways for ED imaging criteria, which were not affected during the pandemic. Thus, it would seem reasonable to suggest that the threshold for ordering diagnostic imaging studies would not have changed significantly for those patients who did present to our ED during the pandemic.

While the imaging rate in April 2021 remained lower than predicted, the decrease was not as great as that seen earlier in the pandemic. This suggests that, while it was not yet over,

the decreasing effects of the pandemic on the health and function of the community at that time were accompanied by a shift towards baseline patient behaviors.

Rate of positive imaging and admittance

Several studies demonstrate that patients who presented to pediatric EDs during the pandemic often presented with higher acuity and rates of complications, suggesting that patients were delaying care [17, 26, 37]. Rates of appendiceal perforation have reportedly been higher in both pediatric and adult studies during the pandemic [38–41]. Unexpectedly decreased diagnoses of acute coronary syndromes and strokes in EDs, associated with increased out-of-hospital mortality rates for these conditions, further suggest that many acute illnesses went undiagnosed [6]. These worrisome trends were reported internationally within nations heavily affected by COVID-19.

We found a comparatively increased odds of positive imaging diagnoses during the pandemic, consistent with studies demonstrating increased percentages of higher acuity ED patients during the COVID-19 pandemic. However, given that both the number of observed positive imaging diagnoses and the observed admission rates for those positive studies in April 2020 and April 2021 were within the predicted range based on previous years, it seems probable that children were appropriately presenting to the ED for urgent conditions, and that there were not undue rates of delayed diagnoses or conditions that went undiagnosed. The overall distribution of common indications for imaging was similar across all years.

During the worst months of the pandemic, many pediatric patients were transferred or diverted to dedicated pediatric hospitals such as ours, as general hospitals prepared for excess numbers of adult COVID-19 patients [42, 43]. It is possible that higher acuity patients were consequently transferred or diverted to our ED, potentially increasing our rate of observed positive imaging studies. One academic pediatric ED study reported a higher proportion of referrals and ambulance arrivals during the same period [14]. A Canadian study found that parents were more likely to visit the ED at a dedicated children's hospital rather than at a general hospital, possibly to minimize exposure to other adults with COVID-19 [17].

As with imaging rate, the odds of positive diagnosis in April 2021 were closer to the pre-pandemic value than in April 2020. At the hospital level, this may have been related to changing policies at healthcare facilities, which resumed care for non-urgent visits, and had more infrastructure in place to continue efficient urgent and emergent care. At the patient level, this change may reflect a return to normalcy in patient behavior, namely in the return of lower acuity patients to the ED.

Limitations and further areas of study

There are several limitations to this study. The 1-month time period studied across years limits the number of radiology studies for analysis. April 2020 was the month of greatest decline in ED patient volume during the pandemic. It therefore likely reflected the time period when patient/family and physician behavior were most affected by the COVID-19 pandemic. Our study focuses on the Emergency Radiology experience during the pandemic and cannot differentiate the effects of patient choice and behavior from potential changes in ED practice patterns, particularly regarding patient imaging. Furthermore, we cannot know with confidence how rates of presentation to the ED were influenced by behavioral changes related to fear and anxiety of exposure to COVID-19, the economic impact of the pandemic resulting in unemployment, and decreased access to healthcare, childcare, and transportation. We may have seen a higher percentage of positive imaging exams during the pandemic compared to prior years because pediatric patients were shifted away from general hospitals that were focusing on adult COVID patients. A broader study of pediatric imaging in the region would be necessary to assess the degree to which such patient transfers or diversions may have influenced our results. Further study is also needed to determine how pediatric ED imaging is affected by evolving developments in the COVID-19 pandemic, as new waves of infections and additional viral variants emerge.

Conclusion

During the COVID-19 pandemic, significantly fewer ED patients underwent imaging for non-COVID-related illnesses than would have been predicted based on imaging patterns for the immediately preceding 3 years. However, the odds of positive diagnosis increased such that the number of positive diagnoses and rate of hospital admission for those studies were within the expected range based on prior years. This suggests that the pandemic did not result in a substantial number of missed diagnoses or severely delay the diagnosis of non-COVID-related conditions in our pediatric ED, although studies from other institutions have indicated otherwise. Imaging volumes in 2021 suggested a return towards baseline patient behavior as the pandemic conditions improved. Greater understanding of trends in emergency imaging during public health crises is necessary to allow proactive measures to facilitate timely and appropriate radiologic care when crises arise.

Author contribution The first draft of the manuscript was written by Wendy Kim. Wendy Kim and Delma Jarrett were responsible for project idea, data, collection and analysis. Patrick Johnston performed statistical analysis. Joshua Nagler and Stephen Brown advised and added information regarding clinical perspective and patient access. All authors commented and edited the manuscript.

Availability of data and material The authors declare that they had full access to all of the data in this study and the authors take complete responsibility for the integrity of the data and the accuracy of the data analysis.

Code availability Not applicable.

Declarations

Ethics approval Ethical approval was waived by the institutional review board.

Consent to participate Written patient or guardian consent was waived.

Consent for publication Not applicable.

Conflict of interest The authors declare that they have no conflict of interest.

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