Impact of COVID-19 on the Associated Complications of High-risk Conditions in a Statewide Pediatric Emergency Network

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Abstract:

Background: The COVID-19 pandemic affected the volume and epidemiology of pediatric emergency department (ED) visits. We aimed to determine the rate of associated complications for 16 high-risk conditions in a Michigan state-wide network of academic and community EDs during the pandemic.

Methods: We conducted a cross-sectional study of pediatric ED visits among a network of 5 Michigan health systems during pre-pandemic (3/1/19-3/10/20) and pandemic (3/11/20-3/31/21) periods. Data was collected from the medical record and included patient demographics, ED visit characteristics, procedure codes, and final International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10-CM) diagnosis codes. Selection of codes for 16 high-risk conditions and diagnostic complications were identified using previously described methods. Characteristics of ED visits were compared before versus during the pandemic using chi-squared and Fisher's exact tests. We used multilevel logistic regression to analyze covariates and potential confounders for being diagnosed with a high-risk condition or a complication of a high-risk condition.

Results: 417,038 pediatric ED visits were analyzed. The proportion of patients presenting with

10 of 16 high-risk conditions (including appendicitis, sepsis, stroke) was higher in the pandemic

period compared to pre-pandemic ($p < 0.01$). Despite this, there was no significant increase in the

frequency of complications for any of the 16 high-risk conditions during the pandemic. The

adjusted odds of being diagnosed with appendicitis (pre-pandemic 0.23% vs pandemic 0.52%;

OR 1.19 [CI 95%1.00-1.41]), diabetic ketoacidosis (pre-pandemic 0.16% vs pandemic 0.52%;

2.40 [95% CI 2.07-2.78]), intussusception (pre-pandemic 0.05% vs pandemic 0.07%; 1.64 [95%

CI 1.22-2.21)], and testicular torsion (pre-pandemic 0.10% vs pandemic 0.14%; OR 1.64 [CI

1.18-2.28]) was higher during the pandemic.

Conclusions: Despite a higher proportion of ED visits due to high-risk conditions, there was no

increase in complications, suggesting minimal impact of the pandemic in outcomes of pediatric

ED visits.

Introduction:

Background

The COVID-19 pandemic drastically affected emergency department (ED) patient volumes, with a significant drop in the early stages of the pandemic followed by a gradual return to pre-pandemic levels. Importantly, the epidemiology of ED visits including pediatric ED visits changed over time.[1] Multiple reports early in the pandemic suggested an increase in diagnostic delays and subsequent complications of common pediatric conditions managed in the ED,[2,3] likely due to patients' and caregivers' hesitancy in seeking medical care in EDs due to potential exposure to COVID-19.[4] Children presenting with high-risk conditions, such as appendicitis and diabetic ketoacidosis,[2,3] were of particular concern, as such conditions are not self-limiting and timely diagnosis is required to prevent morbidity and mortality.

Importance

Several studies have described pandemic-related pediatric ED visit epidemiology, associated diagnostic delays, and patient outcomes and complications of specific high-risk conditions. [1-3] Most are limited by being either single-site studies or reporting findings solely from academic pediatric hospitals. As greater than 85% of children seek emergency care in community EDs, it is imperative to include both academic and community EDs in research aiming to describe the impact of the pandemic on pediatric ED visits for high-risk conditions and associated diagnostic complications. As such, the impact of the pandemic on the frequency and complication rate of high-risk pediatric conditions and complications has not been fully explored.

Goals of this Investigation

The aims of this project were to determine the frequency of 16 high-risk conditions and associated complications in a Michigan state-wide network of academic and community EDs during the first year of the COVID-19 pandemic.

Methods:

Study Design

We conducted a cross sectional study of pediatric patients (0-18 years) among a statewide network of EDs. The Michigan Pediatric Emergency Medicine (MiPEM) Network is composed of 14 EDs from 5 Michigan health systems with representation from community and academic sites which include eleven general EDs and three pediatric-specific EDs. All ED visits to participating sites were included in the pre-pandemic (3/1/19-3/10/20) and pandemic (3/11/20-3/31/21) time periods. This study was approved by the institutional review board for each participating site.

Measurements:

We collected data from the electronic health record (EHR) including patient demographics (age, sex, race, ethnicity), date of visit, emergency severity index [ESI] triage level, mode of arrival, disposition, procedure codes, encounter International Classification of Diseases, 10th Revision (ICD-10-CM) codes, COVID-19 viral testing, and results of viral testing (if applicable).

We defined the sixteen high-risk conditions and their associated complications using ICD-10 diagnosis and procedure codes as described by Michelson et al.[5] The high-risk conditions studied were appendicitis, bacterial meningitis, compartment syndrome, diabetic ketoacidosis, ectopic pregnancy, empyema, encephalitis, intussusception, mastoiditis, myocarditis, orbital cellulitis, ovarian torsion, sepsis, septic arthritis, stroke, and testicular torsion. Diagnoses and procedures suggesting complications included conditions such as perforated appendicitis, bowel resection,

abdominal abscess drainage (for appendicitis); seizure, mechanical ventilation, neurosurgery, death (for bacterial meningitis), orchiectomy (for testicular torsion), and debridement, amputation (for compartment syndrome), etc. A full list of the ICD-10 codes for the high-risk diagnoses and corresponding high-risk conditions can be found in Appendices 1 and 2.

Statistical Analysis

The frequency and proportions for each category were presented for each categorical variable; chi-square and Fisher's exact tests were used to test the distribution difference between the pre- and post-pandemic period. For conditions with sufficient sample size (minimum of 50), we analyzed covariates and potential confounders (age, gender, race/ethnicity, mode of arrival and disposition) for the diagnosis of a high-risk conditions (appendicitis, diabetic ketoacidosis, intussusception, sepsis, and testicular torsion). We also analyzed the odds of being diagnosed with a complication for three of the high-risk conditions with sufficient sample size (appendicitis, diabetic ketoacidosis, and testicular torsion) using multilevel logistic regression with a random intercept of the ED site. The significance level was 0.05. All analyses were performed using SAS 9.4.

Results:

We analyzed 417,038 pediatric ED encounters; 68% (284,346) of visits occurred in the pre-pandemic period (Table 1), representing a 53% decreased during the pandemic period. A higher proportion of patients arrived via ambulance or medical flight (vs personal vehicle) during the pandemic compared to the pre-pandemic period (7.0% vs 4.7%, respectively; $p<0.001$). Additionally, an increased percentage of patients were triaged as ESI Level 1-3 (vs level 4 or 5) during the pandemic when compared to prior (63.5% vs 57.6%, respectively; $p<0.001$). There was also an increase in the percentage of patients admitted to or observed in the hospital during the pandemic compared to the pre-pandemic period (10.5% vs 7.8%, respectively; $p<0.001$). The overall number of deaths in the ED was small, but the number of

deaths in the ED was higher during the pandemic compared to prior (105 patients [0.08%] vs 70 patients [0.02%], respectively). Only 17% (22,583) of children in the study population underwent COVID-19 testing, and among those, 1% (1,309 children) tested positive for COVID-19 infection.

The frequency of select high-risk conditions and associated complications of those high-risk conditions during the pre-pandemic and pandemic periods is shown in Table 2. The proportion of patients presenting with appendicitis, bacterial meningitis, diabetic ketoacidosis, intussusception, myocarditis, ovarian torsion, testicular torsion, sepsis, septic arthritis, and stroke was higher in the pandemic period compared to prior ($p < 0.05$). The raw case counts for diabetic ketoacidosis, myocarditis, stroke, and testicular torsion increased during the pandemic. Despite this, no statistically significant increases in the frequency of complications during the pandemic period compared to pre-pandemic period were identified for any of the 16 conditions.

Results of multilevel logistic regression for diagnosis of five select conditions are shown in Table 3. When controlling for all other variables, the adjusted odds of being diagnosed with appendicitis (pre-pandemic 0.23% vs pandemic 0.52%; OR 1.19 [CI 95%1.00-1.41]), diabetic ketoacidosis (pre-pandemic 0.16% vs pandemic 0.52%; 2.40 [95% CI 2.07-2.78]), intussusception (pre-pandemic 0.05% vs pandemic 0.07%; 1.64 [95% CI 1.22-2.21)], and testicular torsion (pre-pandemic 0.10% vs pandemic 0.14%; OR 1.64 [CI 1.18-2.28]) was higher
during the pandemic.

Additional results of multilevel regression to assess for odds of being diagnosed with a complication of a high-risk condition are included as supplemental material. For patients with the diagnosis of appendicitis, the odds of having a complication were independently associated with age, sex, and arrival mode. Patients aged 1-4 years (OR 3.64 [95% CI 2.03-6.51]), male patients, and those arriving by ambulance/medical flight (OR 1.9 [95% CI 2.36-2.67]) had higher adjusted odds of having

a complication of appendicitis. Patients aged 5-9 years (OR 1.75 [95% CI 1.05-2.93]) and non-Hispanic Black children (OR 1.54 [95% CI 1.02-2.35]) had an increased odds of being diagnosed with a complication of diabetic ketoacidosis. For children with appendicitis, diabetic ketoacidosis, or sepsis, the pandemic period was not independently associated with risk of having of a complication of their high-risk condition.

Limitations

This study has several limitations. High-risk conditions and associated complications were identified via diagnosis codes, which may be susceptible to coding errors. Additionally, data is reported from a single state. Although not reflective of the national or global experience, the MiPEM network includes academic and community centers as well as general and pediatric EDs and likely provides an accurate representation of statewide pediatric ED visits. Finally, this study reflects data from the first year of the COVID-19 pandemic. The availability of COVID-19 viral testing and diagnosis codes were variable in the first few months of the pandemic and may not be fully reflected in this data.

Discussion:

Our results were consistent with prior reports noting a significant decrease in pediatric ED visit volumes during the pandemic period.[1] Despite a decrease in the absolute number of ED visits during the pandemic period, visits were higher acuity, as reflected by the proportional increase in arrivals by EMS/medical flight, patient admissions, deaths in the ED, and ESI triage categorization. Despite an increase in the frequency of 10 of the 16 high-risk conditions studied, the rate of complications was unchanged for all 16 conditions.

Five of the conditions (appendicitis, diabetic ketoacidosis, myocarditis, stroke, and testicular torsion) also had a higher case count during the pandemic period compared to prior despite an overall decrease in patient volume. In considering the potential etiologies for this notable change,

COVID-19-related inflammation, post-infectious inflammatory response, and direct viral injury have been proposed in the pathophysiology of these conditions.[6-8] Given the limited availability of COVID-19 testing at the time of this study, it is unclear how many pediatric patients had COVID-19 related illness or exposure contributing to their clinical presentations. What is evident, however, is that the pandemic alone, when accounting for other variables, conveyed an increased adjusted odds of being diagnosed with several of these high-risk conditions. Clearly, ongoing study into the pathogenic effects of COVID-19 are warranted to better understand the risk of these high-risk conditions and associated complications in relation to the pandemic.

Despite the increase in proportion of high-risk conditions during the pandemic, we found no increase in complications for any of the 16 conditions studied. This is contrary to the many initial reports suggesting increased diagnostic delays and complications in the pandemic period.[2-3] Several subsequent studies support our findings: a recent systematic review and metanalysis of children presenting with testicular torsion during the pandemic found that the rate of delayed presentations and orchiectomy did not significantly differ in the pandemic period compared to prior.[9] A single site study in Spain found no increase in the incidence of complicated appendicitis in pediatric patients during the pandemic period, though this study was from a single institution and comprised only 151 patients.[10]

It is reassuring to confirm that despite an increase in the frequency of several high-risk conditions during the pandemic, the rate of complications of these conditions did not increase. The lack of increased complications is likely multifactorial. One hypothesis entails the role of over-crowding in relation to diagnostic error. It is conceivable that with lower ED patient volumes and fewer competing priorities, clinicians had more time to assess each patient and think critically about each case. Another possible theory involves caregivers' intuition and ability to recognize when their child is seriously ill. Despite parental-reported concerns about presenting to the ED during a pandemic,[4] our data suggests that most caregivers are ultimately able to discriminate between non-

urgent and urgent/emergent illness and seek ED care when indicated. This data suggests visits during the pandemic were of higher acuity and that more people used the ED for urgent and emergent health care crises, rather than non-acute health concerns. This is consistent with prior research demonstrating a decrease of *low-resource-intensity* pediatric ED visits (visits that do not result in hospital admission or medication administration and for which no laboratory tests, diagnostic imaging, or procedures are performed) during the pandemic period compared to prior.[1]

Overall, the pandemic had many complex effects on pediatric patients, their caregivers, and clinicians. The role of COVID-19 in the development of high-risk conditions, lack of related complications, and reasons for these findings warrants further investigation.

In summary, during the first year of the COVID-19 pandemic, pediatric ED visits were lower in volume but higher in acuity. There was an increase in the proportion of presentations due to high-risk conditions, however, there was no increase in associated complications.

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Table 1. Patient and Visit Characteristics for Pediatric ED Encounters in Michigan

	Overall	Pre-pandemic (3/1/19-3/10/20)	Pandemic (3/11/20-3/31/21)	P value
	417,038	284,346 (68.2)	132,692 (31.8)	
Patient Age				
<1 year	51,433 (12.3)	32,194 (11.3)	19,239 (14.5)	<0.001
1-4 years	137,264 (32.9)	98,058 (34.5)	39,206 (29.5)	
5-9 years	86,514 (20.7)	65,625 (23.1)	20,889 (15.7)	
10-14 years	76,083 (18.2)	48,971 (17.2)	27,112 (20.4)	
15-18 years	65,744 (15.8)	39,498 (13.9)	26,246 (19.8)	
Patient Sex (n= 417,024)				
Male	213,990 (51.3)	147,262 (51.8)	66,728 (50.3)	<0.001
Female	203,034 (48.7)	137,079 (48.2)	65,955 (49.7)	
Race & Ethnicity				
Non-Hispanic Black	152,201 (36.5)	107,719 (37.9)	44,482 (33.5)	<0.001
Non-Hispanic White	119,940 (28.8)	79,957 (28.1)	39,983 (30.1)	
Hispanic	78,461 (18.8)	51,706 (18.2)	26,755 (20.2)	
Other	66,436 (15.9)	44,964 (15.8)	21,472 (16.2)	
Arrival Mode				
Ambulance/medical flight	22,529 (5.4)	13,241 (4.7)	9,288 (7.0)	<0.001
Personal vehicle / walk-in	382,852 (91.8)	263,962 (92.8)	118,890 (89.6)	
Other or unknown	11,657 (2.8)	7,143 (2.5)	4,514 (3.4)	
Disposition (n= 415,571)				
Admission/Observation	36,026 (8.7)	22,230 (7.8)	13,796 (10.5)	<0.001
Discharge	368,676 (88.7)	255,432 (89.9)	113,244 (86.1)	
Death in ED	175 (0.04)	70 (0.02)	105 (0.08)	
Other+	10,869 (2.6)	6,334 (2.2)	4,535 (3.4)	

Covid Test (n= 417.027)				
No test	394,439 (94.6)	284,341 (100.0)	110,098 (83.0)	<0.001
Tested negative	21,279 (5.1)	5 (0.0)	21,274 (16.0)	
Tested positive	1,309 (0.3)	0 (0.0)	1,309 (1.0)	
ESI Acuity (*n= 281,761)				
1	2,101 (0.7)	1,224 (0.7)	877 (0.9)	<0.001
2	41,810 (14.8)	25,371 (13.6)	16,439 (17.3)	
3	123,792 (43.9)	80,841 (43.3)	42,951 (45.3)	
4	99,639 (35.4)	69,234 (37.0)	30,405 (32.1)	
5	14,419 (5.1)	10,228 (5.5)	4,191 (4.4)	

+Other: Left without being seen, Left without completing treatment, Left against medical advice, Transfer/Send to another location, Elected to go to urgent care, and Nurse only visits.

*4/5 health systems reporting

Table 2. Frequency of High-Risk Conditions and Associated Complications during the Pre-Pandemic and Pandemic Periods

	Frequency of High-Risk Conditions				**Frequency of Complications of High-Risk Conditions**			
	Overall	**Pre-pandemic (3/1/19-3/10/20)**	**Pandemic (3/11/20-3/31/21)**	**P value**	**Overall**	**Pre-pandemic (3/1/19-3/10/20)**	**Pandemic (3/11/20-3/31/21**	**P value**
All Visits	417,038	284,346 (68.2%)	132,692 (31.8%)					
Appendicitis	1321 (0.317)	641 (0.225)	680 (0.513)	<0.001	375/1321 (28.4)	175/641 (27.3)	200/680 (29.4)	0.39
Bacterial Meningitis	51 (0.012)	26 (0.009)	25 (0.019)	0.0083	24/51 (47.1)	9/26 (34.6)	15/25 (60.0)	0.07
Compartment Syndrome	12 (0.003)	9 (0.003)	3 (0.002)	0.6121	4/12 (33.3)	3/9 (33.3)	1/3 (33.3)	0.99

Diabetic Ketoacidosis	1137 (0.273)	445 (0.157)	692 (0.522)	<0.001	180/1137 (15.8)	74/445 (16.6)	106/692 (15.3)	0.55
Ectopic Pregnancy	15 (0.004)	9 (0.003)	6 (0.005)	0.4963	2/15 (13.3)	2/9 (22.2)	0/6 (0.0)	0.21
Empyema	33 (0.008)	19 (0.007)	14 (0.011)	0.1908	16/33 (48.5)	9/19 (47.4)	7/14 (50.0)	0.88
Encephalitis	16 (0.004)	10 (0.004)	6 (0.005)	0.6255	6/16 (37.5)	2/10 (20.0)	4/6 (66.7)	0.06
Intussusception	217 (0.052)	127 (0.045)	90 (0.068)	0.0023	5/217 (2.3)	3/127 (2.4)	2/90 (2.2)	0.95
Mastoiditis	86 (0.021)	66 (0.023)	20 (0.015)	0.0882	7/86 (8.1)	5/66 (7.6)	2/20 (10.0)	0.73
Myocarditis	12 (0.003)	3 (0.001)	9 (0.007)	0.0013	5/12 (41.7)	2/3 (66.7)	3/9 (33.3)	0.31
Orbital Cellulitis	21 (0.005)	14 (0.005)	7 (0.005)	0.8815	3/21 (14.3)	2/14 (14.3)	1/7 (14.3)	0.99
Ovarian Torsion	67 (0.016)	34 (0.012)	33 (0.025)	0.0022	5/67 (7.5)	5/34 (14.7)	0/33 (0.0)	0.02
Sepsis	478 (0.115)	286 (0.101)	192 (0.145)	0.0001	94/478 (19.7)	61/286 (21.3)	33/192 (17.2)	0.26
Septic Arthritis	61 (0.015)	34 (0.012)	27 (0.020)	0.0369	8/61 (13.1)	5/34 (14.7)	3/27 (11.1)	0.68
Stroke	37 (0.009)	14 (0.005)	23 (0.017)	0.0001	11/37 (29.7)	4/14 (28.6)	7/23 (30.4)	0.90
Testicular Torsion	220 (0.053)	94 (0.033)	126 (0.095)	<0.001	0/220 (0)	0/94 (0)	0/126 (0)	0.99

Table 3. Odds ratio of diagnosis of a high-risk condition during the pandemic period (reference: pre-pandemic)

Condition	Adjusted Odds Ratio (95% CI)*	P value
Appendicitis	1.19 (1.00-1.41)	0.052
Diabetic Ketoacidosis	2.40 (2.07-2.78)	<.0001
Intussusception	1.64 (1.22-2.21)	0.001
Sepsis	0.96 (0.71-1.31)	0.802
Testicular Torsion	1.64 (1.18-2.28)	0.003

CI: Confidence Interval

*After adjusting for age, race/ethnicity, gender, mode of arrival, and disposition

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