

## ORIGINAL RESEARCH

## Pediatrics

# Comparing two definitions of pediatric complexity among children cared for in general and pediatric emergency departments in a statewide sample

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**Abstract**

**Objective:** The number of children cared for in emergency departments (EDs) with medical complexity continues to rise. We sought to identify the concordance between 2 commonly used criteria of medical complexity among children presenting to a statewide sample of EDs.

**Methods:** We conducted a retrospective cross-sectional study of children presenting to a statewide sample of Illinois EDs between 2016 and 2021. We classified patients as having medical complexity when using 2 definitions ( $\geq 1$  pediatric Complex Chronic Condition [CCC] or complex chronic disease using the Pediatric Medical Complexity Algorithm [PMCA]) and compared their overlap and clinical outcomes.

**Results:** Of 6,550,296 pediatric ED encounters, CCC criteria and PMCA criteria were met in 217,609 (3.3%) and 175,708 (2.7%) encounters, respectively. Among patients with complexity, 100,015 (34.1%) met both criteria, with moderate agreement ( $\kappa = 0.49$ ). Children with complexity by CCC had similar rates of presentation to a pediatric hospital (16.3% vs 14.8%), admission (28.5% vs 33.7%), ICU stay (10.0% vs 10.1%), and in-hospital mortality (0.5% vs 0.5%) compared to children with complexity by PMCA. The most common visit diagnoses for children with CCCs were related to sickle cell disease with crisis (3.9%), abdominal pain (3.6%), and non-specific chest pain (2.7%). The most common diagnoses by PMCA were related to depressive disorders (4.9%), sickle cell disease with crisis (4.8%), and seizures (3.2%).

**Conclusions and Relevance:** The CCC and PMCA criteria of multisystem complexity identified different populations, with moderate agreement. Careful selection of operational definitions is required for proper application and interpretation in clinical and health services research.

**KEYWORDS**

children with medical complexity, complex chronic conditions, complex chronic disease, emergency care, pediatric medical complexity algorithm

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## 1 | INTRODUCTION

### 1.1 | Background

Children with medical complexity represent a small but growing proportion of patients cared for in the acute care setting.<sup>1-3</sup> These children are defined as having “multiple significant chronic health problems involving multiple organ systems, which result in functional limitations, high health care needs or utilization, and often requires need for, or use of, medical technology.”<sup>4</sup> Children with medical complexity have a high use of the emergency department (ED), and such encounters result in longer lengths of stay, higher resource use, and more frequent hospitalizations compared to children without these conditions.<sup>5-9</sup>

The management of medically complex children remains a challenge for ED clinicians.<sup>10-12</sup> The number of children with medical complexity cared for in hospitals continues to increase.<sup>2</sup> One systematic review evaluating the role of specialized ambulatory clinics in preventing unnecessary ED encounters for medically complex children had to reconcile varying criteria of pediatric medical complexity among the 16 included studies.<sup>13</sup> These differences in criteria make it challenging to interpret research about these children.

Two common classification criteria that are in wide use are the Complex Chronic Conditions (CCC)<sup>14</sup> and the Pediatric Medical Complexity Algorithm (PMCA).<sup>15</sup> Both are diagnosis-based classifications of organ system involvement that are publicly available and versatile to apply toward administrative data sets. Other criteria for determining medical complexity in children using administrative data are either proprietary<sup>16</sup> or are not pediatric specific.<sup>17</sup> These criteria vary in significant ways: CCC, for example, does not include mental and behavioral health conditions, whereas PMCA does. Furthermore, CCC has a dedicated process to identify children with technology dependence, whereas PMCA includes categories for the complexity of a patient's condition-based involvement of  $\geq 2$  body systems, progressivity, or malignancy.

Most research evaluating the care of medically complex children has been limited to the care within tertiary care pediatric hospitals.<sup>2,5,6,8,9,18-20</sup> Less is known about the care of medically complex children in non-pediatric hospitals.<sup>6,22</sup> Although pediatric EDs encounter a higher proportion of children with medical complexity than general EDs, general EDs continue to care for a greater number of medically complex children.<sup>22</sup> Given the considerable health care requirements of these children, greater familiarity with the unique challenges in caring for these children is essential for the general ED clinician.<sup>23</sup>

### 1.2 | Goals of this investigation

We sought to identify the concordance between 2 commonly used criteria of medical complexity among children presenting to a statewide sample of EDs.

#### The Bottom Line

Children with medical complexities are an increasing population seen in the emergency department (ED), and it is important to be able to identify these patients quickly to meet their medical needs. This manuscript evaluates 2 criteria to determine the extent of illness in these patients as used in non-tertiary EDs. This is important because most research has been done in large tertiary care centers but more of these patients will come to non-tertiary EDs.

## 2 | METHODS

### 2.1 | Study design, setting, and selection of participants

We performed a multicenter cross-sectional study of general and pediatric ED encounters using data from 194 Illinois hospitals (approximately 90% of hospitals in the state)<sup>24</sup> between 2016 and 2021 using COMPdata Informatics. COMPdata is an administrative database associated with the Illinois Health and Hospital Association that includes non-federal community, academic, and tertiary care sites within the state.<sup>25</sup> As the association is data collection agency for the Illinois Department of Public Health, submissions are required to be  $\geq 98\%$  error free. To construct the database, each facility's billing vendor submits a data file. COMPdata applies edits to the submission and audits these data. Additionally, each facility can manually correct data on the error correction screen or resubmit the file to correct any errors in their data. At the close of each quarter, additional quality checks are done before the release of the downloadable data set. We included all encounters for patients  $< 21$  years with an associated ED encounter, which were defined and identified using claim revenue codes (0450-0459 for ED; 0680-0689 for trauma responses). We did not apply exclusions. This investigation was approved by our institutional review board.

### 2.2 | Measurements

We used the following demographics: age, sex, race/ethnicity, and insurance status. We considered race as a composite variable with ethnicity, classified as follows: White non-Hispanic, Black non-Hispanic, Hispanic/Latino, all others, or missing.<sup>26,27</sup> Insurance status was classified as public, private, other, or unknown. We identified encounters transferred to the ED from another hospital. We calculated the centroid distance from each encounter's home postal code to the ED in kilometers (km) and categorized this variable into distances of 0 to  $< 5$  km (about 3 miles), 5 to  $< 10$  km (about 6 miles), 10 to  $< 20$  km (about 12 miles) and  $\geq 20$  km. From each patient's home postal code,

**TABLE 1** Studied criteria.

Criteria	Complex Chronic Condition	Chronic complex criteria of Pediatric Medical Complexity Algorithm <sup>a</sup>
Core definition	Condition that “can be reasonably expected to last at least 12 months (unless death intervenes) and to involve either different organ systems or 1 organ system severe enough to require specialty pediatric care and probably some period of hospitalization in a tertiary care center.”	One of the following <ol style="list-style-type: none"> <li>1. A significant chronic condition in 2 or more body systems</li> <li>2. A progressive condition that is associated with deteriorating health with a decreased life expectancy in adulthood</li> <li>3. Associated with continuous dependence on technology lasting for at least 6 months</li> <li>4. A metastatic or progressive malignancies that affect life function, (excluding those in remission for &gt;5 years)</li> </ol>
Description	Diagnosis and procedure ICD-10-CM based classification based on all diagnoses	Classified using ICD-10-CM diagnosis codes into 18 types
Mental health inclusion	No	Yes
Categories	Ten mutually exclusive categories: (neuromuscular, cardiovascular, respiratory, renal, gastrointestinal, hematology/immunology, metabolic, malignancy, congenital/genetic, and neonatal). Two non-mutually exclusive categories: technology dependence and transplant	Craniofacial, dermatologic, endocrine, hematologic, genitourinary, genetic, gastrointestinal, immunological, behavioral, metabolic, musculoskeletal, pulmonary, renal, ophthalmologic, otologic, and cardiac. Patients with chronic disease can be additionally classified as having “progressive” and “non-progressive” disease
Reference	Feudtner et al. (2014) <sup>14</sup>	Simon et al (2018) <sup>15</sup>

Abbreviation: ICD-10-CM, International Classification of Disease, Tenth Revision, Clinical Modification.

<sup>a</sup>Adapted for the present study. As described by Simon et al., Pediatric Medical Complexity Algorithm criteria are recommended to incorporate multiple years of inpatient and outpatient data sources.

we identified the Child Opportunity Index 2.0 (COI), which uses 29 neighborhood-level indicators to construct a 5-tiered composite score ranging from very high to very low.<sup>28</sup> We determined if the encounter occurred at a pediatric hospital.

We classified primary diagnoses using Pediatric Clinical Classification System, which separates *International Classification of Diseases, Tenth Revision* (ICD-10) codes into pediatric-specific, mutually exclusive categories.<sup>29</sup> We used Current Procedural Terminology (CPT) codes to classify encounter acuity as low (CPT 99281 and 99282), medium (CPT 99283), and high (CPT 99284 and 99285) and to identify diagnostic testing performed. Laboratory tests included complete blood count, blood culture, liver/electrolyte testing, urinalysis, and urine culture. Diagnostic imaging included computerized tomography of the head, magnetic resonance imaging of the head, abdominal ultrasound, abdominal radiography, chest radiography, and echocardiography. Clinical testing included lumbar puncture, electroencephalogram, and electrocardiogram. The COMPdata data set does not differentiate between diagnostic testing performed during the ED encounter or later during the hospitalization. We evaluated for the following dispositions: admission, transfer to another facility, hospital length of stay, and in-hospital mortality.

### 2.3 | Outcomes

Our outcome of interest was medical complexity. We compared 2 classification criteria: CCC and the complex chronic disease definition

of PMCA (Table 1). There were 29 available diagnosis code positions for each encounter. We used all the available diagnoses for encounter classification. The CCC, characterized by Feudtner et al is a criteria which identifies diagnoses that are expected to last at least 12 months or increase the risk of hospitalization in a tertiary care hospital.<sup>14</sup> Diagnosis codes may be grouped into 1 of 10 mutually exclusive categories by relevant ICD-10 codes. Each code may additionally be associated with the categories of technology dependence, transplant, or both.

The PMCA classifies each diagnosis code into 1 of 18 mutually exclusive body system categories, with an additional measure of progressivity. We used the “least conservative” PMCA criteria.<sup>30</sup> The assignment of PMCA categories typically requires longitudinal data for 3 years.<sup>15</sup> However, as COMPdata has only encounter-level data, we limited our classification to diagnoses present on each ED visit alone on the basis of our prior work among children admitted to children’s hospitals suggesting that including longitudinal data resulted in only a marginal increase in the number of identified cases (approximately 5%).<sup>31</sup>

### 2.4 | Data analyses

After categorizing patients, we calculated Cohen’s kappa ( $\kappa$ ) to assess the agreement between the CCC and complex chronic disease PMCA criteria. We interpreted  $\kappa$  results as follows:  $\geq 0.8$  as almost perfect agreement, 0.61 to 0.79 as substantial, 0.41 to 0.60 as moderate, 0.21

to 0.40 as fair, and 0 to 0.20 as slight agreement.<sup>32</sup> We reported the most common diagnoses within each subgroup. We did not perform statistical tests of difference due to overlapping subgroups. We calculated the Cohen's  $\kappa$  between CCC and PMCA when the criteria for complexity with CCC ranged from  $\geq 1$  to  $\geq 4$  CCCs. We described the demographic and treatment characteristics of increased counts of CCC and within the 12 categories of CCCs. Among encounters with a CCC or a complex chronic condition of the PMCA criteria, we compared characteristics among children treated at pediatric versus non-pediatric hospitals. We evaluated demographic and treatment characteristics of complexity in mutually exclusive categories. As a post hoc analysis, to evaluate whether our findings may have been affected by changes in ED care related to the COVID-19 pandemic,<sup>40</sup> we characterized encounters of children with complexity over time in mutually exclusive subgroups. Analyses were performed using the *pccc* (v1.0.5)<sup>33</sup> and *psych* (v2.1.9)<sup>34</sup> packages in R, version 4.1.2 (R Foundation for Statistical Computing, Vienna, Austria).

### 3 | RESULTS

#### 3.1 | Inclusion

We identified 6,550,296 pediatric encounters during the study years. The median age was 9 years (interquartile range, 3–16), with a female predominance (51%; Table 2). Almost two thirds of encounters were from children within 10 km of the hospital. Only 5.0% of encounters were at a pediatric hospital.

**CCCs.** Overall, 217,609 (3.3%) encounters had  $\geq 1$  CCC, 61,397 (0.9%) had  $\geq 2$  CCCs, 23,100 (0.4%) had  $\geq 3$  CCCs, and 9,087 (0.1%) had  $\geq 4$  CCCs. Among encounters with  $\geq 1$  CCC, the most common qualifying diagnoses were gastrointestinal disease (49,669, or 22.8%), technology dependence (45,878, 21.1%), and cardiovascular disease (44,532, 20.5%). Of the 217,609 children with  $\geq 1$  CCC, a higher proportion were seen at pediatric hospitals (16.3%) compared to patients without complexity. Compared to children without complexity, patients with complexity by CCC criteria more frequently lived further from the hospital. These children had a similar racial and ethnic distribution, payor status, and COI status compared to patients without complexity. Compared to children without medical complexity, children with CCCs were more frequently admitted (28.5% vs 2.3%), transferred (3.7% vs 1.5%), required care in an ICU (10.0% vs 0.4%), and had higher in-hospital mortality (0.5% vs < 0.1%; Table 3). They additionally had more diagnostic testing performed for all studied tests compared to children without medical complexity. Hospitalization, transfer, ICU admission, and mortality increased with more CCCs (Tables S1 and S2). Children treated at pediatric hospitals more frequently had a greater number of CCCs and had longer lengths of stay but a similar proportion of in-hospital mortality compared to children with CCCs treated in a non-pediatric hospital (Table S3).

**PMCA.** When using the PMCA criteria, most children ( $n = 5,606,029$ , 85.6%) had non-chronic disease, followed by non-complex chronic disease (768,559, 11.7%), and complex chronic disease (175,708, 2.7%).

Overall, 14.4% met at least 1 definition of medical complexity by PMCA. Compared to patients without complexity, children with complex chronic disease were more frequently older, lived further from the hospital, and more frequently presented to a pediatric hospital (14.8%) (Table S4). Children with complex chronic disease had a similar distribution of race/ethnicity status, payor status, and COI as those without medical complexity. Children with complex chronic disease also had greater rates of hospitalization, transfer, ICU admission, and mortality compared to those without complexity, and diagnostic testing was greater in this group. The most common qualifying diagnoses for PMCA among those with complex chronic disease were mental health (72,351, or 41.2% of the PMCA complex chronic disease encounters), pulmonary (64,750, 36.9%), and neurologic (47,560, 27.1%). Children treated at pediatric hospitals more frequently had pulmonary, hematologic and malignancy-related conditions; in contrast, children treated at non-pediatric hospital had a greater proportion of mental health conditions (Table S5).

#### 3.2 | Comparison of criteria for medical complexity

Overall, 293,302 (4.5%) of encounters met at least 1 criterion of medical complexity by having at least 1 CCC or meeting the PMCA criteria of complex chronic disease (Figure 1). The sample identified by CCC was larger (217,609 vs 175,708). Among patients with complexity, 34.1% of children met both CCC and PMCA criteria for complexity. Cohen's  $\kappa$  between these criteria was 0.49, indicating moderate agreement. When evaluating differing counts of CCC with PMCA complex chronic disease, the highest  $\kappa$  was with at least 1 CCC, which decreased with increasing CCCs ( $\kappa = 0.09$  with  $\geq 4$  CCCs).

The most common diagnoses for encounters with children with CCCs were sickle cell disease with crisis, abdominal pain, non-specific chest pain, and diabetic ketoacidosis. The most common encounter reasons for the PMCA criteria were major depressive disorder, sickle cell disease with crisis, and seizures. Among patients without complexity by either metric, the most common diagnoses were acute upper respiratory tract infections, superficial injuries, and otitis media.

Evaluated as mutually exclusive subgroups, patients with overlapping CCC and PMCA criteria were most frequently seen in a pediatric hospital (22.5%), admitted to the hospital (41.3%), admitted to the ICU (14.4%), and had the highest in-hospital mortality (0.7%; Table S6). Our post hoc analysis suggested that encounters with CCC without PMCA, PMCA without CCC, and CCC with PMCA demonstrated similar changes in rates of presentation at the onset of the COVID-19 pandemic, with all declining and subsequently rising again, though not back to prepandemic levels (Figure S1).

### 4 | LIMITATIONS

This was a retrospective, cross-sectional study that used administrative data to evaluate criteria of medical complexity and that may be subject to limitations in coding accuracy. Prior work, for example, has

**TABLE 2** Demographics of the study sample among encounters with complexity, defined as  $\geq 1$  Complex Chronic Conditions (CCC) or Pediatric Medical Complexity Algorithm (PMCA) complex chronic disease.

N (%) or median [IQR]	All ED encounters	$\geq 1$ CCC	PMCA chronic complex disease	No complexity
N	6,550,296	217,609	175,708	6,256,994
Age, years	9 [3, 16]	13 [4, 18]	14 [7, 18]	9 [3, 16]
Male sex	3,208,637 (49.0)	109,136 (50.2)	86,484 (49.2)	3,064,806 (49.0)
Race/ethnicity				
NH White	2,707,398 (41.3)	88,803 (40.8)	74,921 (42.6)	2,580,904 (41.2)
NH Black	1,791,985 (27.4)	65,317 (30.0)	54,565 (31.1)	1,706,621 (27.3)
Hispanic	1,411,647 (21.6)	44,411 (20.4)	31,623 (18.0)	1,355,467 (21.7)
All others	614,576 (9.4)	18,239 (8.4)	13,824 (7.9)	590,534 (9.4)
Missing	24,690 (0.4)	839 (0.4)	775 (0.4)	23,468 (0.4)
Payor status				
Private	2,054,311 (31.4)	79,434 (36.5)	61,563 (35.0)	1,948,174 (31.1)
Public	3,806,590 (58.1)	123,902 (56.9)	103,872 (59.1)	3,639,182 (58.2)
Other, charity, or self	641,171 (9.8)	13,502 (6.2)	9,725 (5.5)	622,501 (9.9)
Missing	48,224 (0.7)	771 (0.4)	548 (0.3)	47,137 (0.8)
Distance to hospital				
0 to <5 km	2,465,878 (37.6)	57,642 (26.5)	49,333 (28.1)	2,382,128 (38.1)
5 to <10 km	1,755,508 (26.8)	52,064 (23.9)	40,465 (23.0)	1,685,246 (26.9)
10 to <20 km	1,392,618 (21.3)	52,208 (24.0)	41,880 (23.8)	1,323,462 (21.2)
$\geq 20$ km	924,144 (14.1)	55,297 (25.4)	43,629 (24.8)	854,597 (13.7)
Missing	12,148 (0.2)	398 (0.2)	401 (0.2)	11,561 (0.2)
Child Opportunity Index				
Very high	706,037 (10.8)	29,608 (13.6)	23,553 (13.4)	666,570 (10.7)
High	1,014,814 (15.5)	37,374 (17.2)	29,370 (16.7)	964,899 (15.4)
Moderate	1,329,282 (20.3)	40,025 (18.4)	31,902 (18.2)	1,274,189 (20.4)
Low	1,624,835 (24.8)	47,478 (21.8)	40,811 (23.2)	1,558,298 (24.9)
Very low	1,862,131 (28.4)	62,680 (28.8)	49,636 (28.2)	1,780,488 (28.5)
Missing	13,197 (0.2)	444 (0.2)	436 (0.2)	12,550 (0.2)
Pediatric hospital status	329,310 (5.0)	35,521 (16.3)	26,088 (14.8)	290,249 (4.6)

Note: Sex unavailable for 342 encounters ( $<0.01$ ).

Abbreviations: ED, emergency department; IQR, interquartile range; Km, kilometers; NH, non-Hispanic.

suggested that ED coding may have variable accuracy when comparing clinical and administrative data sources.<sup>35</sup> This limitation extends to other research using diagnosis-code based coding to identify children with medical complexity. The CCC and PMCA may inadequately or inaccurately capture the lived experience of medically complex children, which a more thorough evaluation of physical needs or functional capacity might reveal. We had to modify our definition of PMCA to be limited only to encounter-level data. However, in our prior work, we demonstrated that the incorporation of longitudinal data resulted in only a small (~5%) increase in cases.<sup>31</sup> We were unable to separate diagnostic testing performed in the ED from those performed during hospitalization. Our findings with respect to ICU may be confounded by regulations within hospitals mandating the use of the ICU for patients with specific forms of technology dependence or diagnoses.

## 5 | DISCUSSION

We evaluated overlap and resource use of children presenting to Illinois EDs with complexity using 2 classification criteria. Children with complexity constituted a small proportion (approximately 3%) of pediatric ED encounters. CCC identified a slightly larger sample, and moderate concordance ( $\kappa = 0.49$ ) was seen between the criteria. Children with complexity had greater resource use compared to those not meeting these criteria, with the greatest identified among those meeting both criteria.

Though the definitions for medical complexity that were studied are constant, their comparison across different settings may suggest differing rates of overlap based on site of care. Different types of patients may exist within a geographic area or present to the ED compared to

**TABLE 3** Treatment factors of the study sample among encounters with complexity, defined as  $\geq 1$  Complex Chronic Condition (CCC) or Pediatric Medical Complexity Algorithm (PMCA) complex chronic disease.

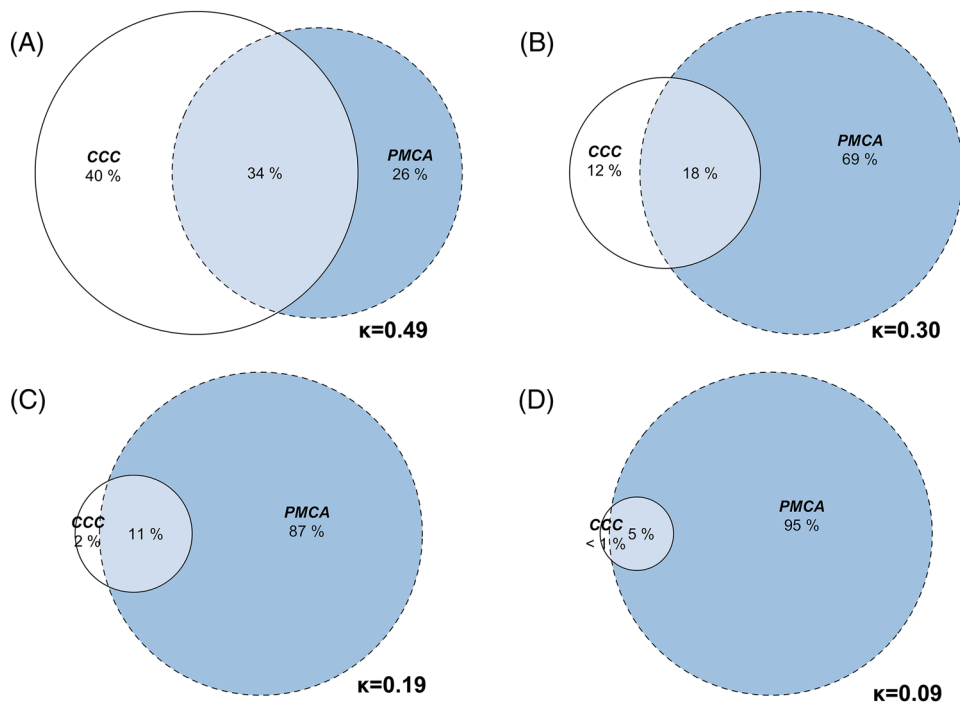
N (%)	All ED encounters	$\geq 1$ CCC	PMCA chronic complex disease	No complexity
N	6,550,296	217,609	175,708	6,256,994
Admission	222,129 (3.4)	62,121 (28.5)	59,165 (33.7)	142,100 (2.3)
Transfer	107,189 (1.6)	8,088 (3.7)	10,843 (6.2)	92,746 (1.5)
ICU admission	48,976 (0.7)	21,746 (10.0)	17,670 (10.1)	24,000 (0.4)
Length of stay, days	1 [1, 1]	1 [1, 3]	2 [1, 3]	1 [1, 1]
In-hospital mortality	3125 (<0.1)	1040 (0.5)	799 (0.5)	2033 (<0.1)
ED billing				
Low	1,350,642 (20.6)	13,252 (6.1)	9794 (5.6)	1,331,973 (21.3)
Medium	3,030,760 (46.3)	45,767 (21.0)	34,381 (19.6)	2,966,995 (47.4)
High	1,983,199 (30.3)	95,266 (43.8)	71,565 (40.7)	1,853,846 (29.6)
Laboratory testing				
CBC	1,199,691 (18.3)	80,631 (37.1)	60,252 (34.3)	1,092,015 (17.5)
Blood culture	132,827 (2.0)	14,894 (6.8)	11,114 (6.3)	116,215 (1.9)
Electrolytes or liver function testing	1,153,050 (17.6)	78,288 (36.0)	57,720 (32.9)	1,047,672 (16.7)
Urinalysis	1,099,109 (16.8)	47,848 (22.0)	34,415 (19.6)	1,033,960 (16.5)
Urine culture	342,210 (5.2)	14,567 (6.7)	10,354 (5.9)	323,553 (5.2)
Diagnostic imaging				
CT head	225,959 (3.4)	10,818 (5.0)	7654 (4.4)	211,108 (3.4)
MRI head	10,668 (0.2)	2795 (1.3)	1774 (1.0)	7336 (0.1)
Abdominal ultrasound	105,425 (1.6)	5787 (2.7)	2899 (1.6)	98,549 (1.6)
Abdominal radiograph	105,748 (1.6)	7650 (3.5)	4039 (2.3)	96,971 (1.5)
Chest radiograph	488,236 (7.5)	27,618 (12.7)	16,864 (9.6)	454,822 (7.3)
Echocardiograph	6394 (0.1)	2096 (1.0)	1099 (0.6)	4029 (0.1)
Clinical testing				
Lumbar puncture	4177 (0.1)	253 (0.1)	172 (0.1)	3831 (0.1)
EEG	4662 (0.1)	828 (0.4)	774 (0.4)	3488 (0.1)
ECCG	346,154 (5.3)	34,730 (16.0)	18,220 (10.4)	302,283 (4.8)

Abbreviations: CT, computerized tomography; ED, emergency department; EEG, electroencephalogram; MRI, magnetic resonance imaging.

those admitted to the hospital or require treatment in an ICU. Our findings in comparing the extent of overlap between the CCC and PMCA for the identification of children with complexity are consistent with recent work performed to compare these criteria among differing patient samples.<sup>31,36,37</sup> The greatest agreement was between  $\geq 1$  CCC and PMCA criteria (as reflected in both the  $\kappa$  and in ED treatment characteristics), but definitions for medical complexity vary widely. The overlap among these criteria among children presenting to a pediatric ICU was substantially higher in 1 multicenter study.<sup>37</sup> Our estimate of children with medical complexity is smaller than that reported in a 3-state study, which estimated that  $>10\%$  of children had met the complex chronic disease definitions of PMCA and/or had at least 1 CCC.<sup>36</sup> Presumably this difference may be because of care-seeking patterns for patients. However, our estimate with respect to CCCs corroborates a study performed with the National Emergency Department Sample, which reported that approximately 2% of children in community EDs had at least 1 CCC.<sup>22</sup> Our findings with PMCA corroborate the

number of children reported to have a complex chronic disease (3%) and a non-complex chronic disease (9%) who receive primary care and are covered by a US commercial insurance payor.<sup>38</sup> We also identify parallels with prior work comparing these 2 criteria among children admitted to a pediatric hospital. In that study, among 402,811 children meeting the PMCA criteria and 157,725 with  $\geq 2$  CCCs, 140,045 (33.3%) met both, resulting in a Cohen's  $\kappa$  of 0.43.<sup>31</sup> The present investigation of pediatric medical complexity among ED encounters from primarily non-pediatric settings corroborates these findings. Both types of patients with medical complexity more frequently presented to pediatric hospitals, were more frequently admitted to the hospital, had longer lengths of stay, underwent more diagnostic testing, and had higher in-hospital mortality compared to the baseline population.

Some of our observed findings relate to important differences between criteria. Although the conceptual framework for medical complexity upon which PMCA is based includes continuous technology dependence, it is not operationalized in the current definition. PMCA



**FIGURE 1** Extent of overlap between complexity criteria, as defined by (A)  $\geq 1$  Complex Chronic Condition (CCC) (B)  $\geq 2$  CCCs, (C)  $\geq 3$  CCCs, and (D)  $\geq 4$  CCCs and complex chronic disease as defined by the Pediatric Medical Complexity Algorithm (PMCA).

includes a category for behavioral disorders, which is not present in the CCC; the most common diagnosis identified in patients solely with this criterion was for depressive disorders.

Our findings carry implications for further research of children with complexity in the ED. For example, researchers who wish to evaluate mental health disorders may gain greater benefit from using the PMCA. Patients meeting both CCC and PMCA criteria appear to have higher proportions of encounters with hospitalization, ICU admission, and in-hospital mortality than patients meeting only 1 of these criteria. However, it is important to note that some measures of resource use, such as ICU use, may be limited in their ability to identify patients with worsened disease acuity given that some patient-level characteristics (such as chronic ventilator use) may require ICU admission based on institutional practices regardless of severity of illness.

For the ED clinician, the specific differences within between the definitions likely carries less weight. An awareness of the frequency with which they present may specifically have import from the standpoint of pediatric readiness. For example, we found that among patients with medical complexity, those with metabolic disorders by the CCC criteria presented more frequently in non-pediatric hospitals compared to pediatric hospitals. Mental health disorders occurred more frequently among non-pediatric hospitals when using the PMCA criteria. Prior work has demonstrated that hospitals with greater pediatric readiness have lower mortality,<sup>39</sup> which is particularly relevant for medically complex children. Our findings with respect to care use have implications for prioritizing pediatric readiness among these hospitals. One cross-sectional analysis reported that while nearly all US children could

travel to an ED within 30 minutes, only one third of children could travel to a hospital that met essential pediatric readiness requirements (defined as a weighted pediatric readiness score of 100) in this time.<sup>41</sup>

In this cross-sectional study of children evaluated in a statewide data set of EDs, we identified that the PMCA and CCC criteria for complexity identified different samples of patients, with moderate agreement between classification criteria. Each identified a distinct population of children, though with similar proportions having hospital admission, ICU admission, and in-hospital mortality. Our finding highlights the need to evaluate care-seeking patterns of children with medical complexity to non-pediatric hospitals, where most of these children obtain care.

#### AUTHOR CONTRIBUTIONS

Sriram Ramgopal designed the study, interpreted the data, carried out the statistical analyses, and drafted the initial manuscript. Julia A. Heneghan conceptualized the study, interpreted the results, and reviewed and revised the manuscript. Both authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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## REFERENCES

- Perrin JM, Bloom SR, Gortmaker SL. The increase of childhood chronic conditions in the United States. *Jama*. 2007;297(24):2755-2759.
- Burns KH, Casey PH, Lyle RE, Mac Bird T, Fussell JJ, Robbins JM. Increasing prevalence of medically complex children in US hospitals. *Pediatrics*. 2010;126(4):638-46.
- Kuo DZ, Melguizo-Castro M, Goudie A, Nick TG, Robbins JM, Casey PH. Variation in child health care utilization by medical complexity. *Matern Child Health J*. 2015;19(1):40-48.
- Kuo DZ, Houtrow AJ, Norwood KW, et al. Recognition and management of medical complexity. *Pediatrics*. 2016;138(6):e20163021.
- O'Mahony L, O'Mahony DS, Simon TD, Neff J, Klein EJ, Quan L. Medical complexity and pediatric emergency department and inpatient utilization. *Pediatrics*. 2013;131(2):e559-e565. doi:10.1542/peds.2012-1455
- Reynolds S, Desguin B, Uyeda A, Davis AT. Children with chronic conditions in a pediatric emergency department. *Pediatr Emerg Care*. 1996;12(3):166-168.
- Weller WE, Minkovitz CS, Anderson GF. Utilization of medical and health-related services among school-age children and adolescents with special health care needs (1994 National Health Interview Survey on Disability [NHIS-D] Baseline Data). *Pediatrics*. 2003;112(3):593-603.
- Massin MM, Montesanti J, Gérard P, Lepage P. Children with chronic conditions in a paediatric emergency department. *Acta Paediatr*. 2006;95(2):208-213.
- Coller RJ, Rodean J, Linares DE, et al. Variation in hospitalization rates following emergency department visits in children with medical complexity. *J Pediatr*. 2019;214:113-120. doi:10.1016/j.jpeds.2019.07.034 e1
- Adams S, Beatty M, Moore C, et al. Perspectives on team communication challenges in caring for children with medical complexity. *BMC Health Serv Res*. 2021;21(1):1-14.
- Pulcini CD, Dubuque A, Lamberson M, et al. Pediatric emergency medicine physicians' perspectives on emergency care of children with medical complexity: a multi-institution mixed-methods assessment. *Pediatr Emerg Care*. 2022;38(8):e1423-1427.
- Pulcini CD, Belardo Z, Ketterer T, Zorc JJ, Mollen CJ. Improving emergency care for children with medical complexity: parent and physicians' perspectives. *Acad Pediatr*. 2021;21(3):513-520.
- Pulcini CD, Coller RJ, Houtrow AJ, Belardo Z, Zorc JJ. Preventing emergency department visits for children with medical complexity through ambulatory care: a systematic review. *Acad Pediatr*. 2021;21(4):605-616. doi:10.1016/j.acap.2021.01.006
- Feudtner C, Feinstein JA, Zhong W, Hall M, Dai D. Pediatric complex chronic conditions classification system version 2: updated for ICD-10 and complex medical technology dependence and transplantation. *BMC Pediatr*. 2014;14(1):199. doi:10.1186/1471-2431-14-199
- Simon TD, Haaland W, Hawley K, Lambka K, Mangione-Smith R. Development and validation of the pediatric medical complexity algorithm (PMCA) version 3.0. *Acad Pediatr*. 2018;18(5):577-580.
- 3M. Clinical Risk Groups (CRGs). Accessed February 9, 2023. [https://www.3m.com/3M/en\\_US/health-information-systems-us/drive-value-based-care/patient-classification-methodologies/crgs/](https://www.3m.com/3M/en_US/health-information-systems-us/drive-value-based-care/patient-classification-methodologies/crgs/)
- Agency for Healthcare Research and Quality. Chronic Condition Indicator Refined (CCIR) for ICD-10-CM. Published 2022. Accessed February 9, 2023. [https://www.hcup-us.ahrq.gov/toolssoftware/chronic\\_icd10/chronic\\_icd10.jsp](https://www.hcup-us.ahrq.gov/toolssoftware/chronic_icd10/chronic_icd10.jsp)
- Pulcini CD, Coller RJ, Macy ML, et al. Low-resource emergency department visits for children with complex chronic conditions. *Pediatr Emerg Care*. 2022;38(2):e856-e862.
- Lion KC, Gritton J, Scannell J, et al. Patterns and predictors of professional interpreter use in the pediatric emergency department. *Pediatrics*. 2021;147(2):e20193312. doi:10.1542/peds.2019-3312
- Auger KA, Shah SS, Huang B, et al. Discharge medical complexity, change in medical complexity and pediatric 30-day readmission. *J Hosp Med*. 2019;14(8):474-481.
- Bucholz EM, Schuster MA, Toomey SL. Trends in 30-day readmission for Medicaid and privately insured pediatric patients: 2010-2017. *Pediatrics*. 2020;146(2):e20200270. doi:10.1542/peds.2020-0270
- Hudgins JD, Monuteaux MC, Bourgeois FT, et al. Complexity and severity of pediatric patients treated at United States emergency departments. *J Pediatr*. 2017;186:145-149. doi:10.1016/j.jpeds.2017.03.035 e1
- Cohen E, Berry JG, Camacho X, Anderson G, Wodchis W, Guttmann A. Patterns and costs of health care use of children with medical complexity. *Pediatrics*. 2012;130(6):e1463-e1470.
- Illinois Department of Public Health. Illinois Hospitals. Accessed January 17, 2022. <http://www.idph.state.il.us/tfhrp/materials/Maphandout.pdf>
- Illinois Health and Hospital Association. COMPdata Informatics. Accessed February 9, 2023. <https://www.compdatainfo.com/Home.aspx>
- Kurz B, Rozas LW. The concept of race in research: using composite variables. *Ethn Dis*. 2007;17(3):560-567.
- Sen M, Wasow O. Race as a bundle of sticks: designs that estimate effects of seemingly immutable characteristics. *Annu Rev Polit Sci*. 2016;19:499-522.
- Acevedo-Garcia D, McArdle N, Hardy EF, et al. The child opportunity index: improving collaboration between community development and public health. *Health Aff*. 2014;33(11):1948-1957.
- Gill PJ, Anwar MR, Thavam T, Hall M, Rodean J, Mahant S. Pediatric clinical classification system for use in inpatient settings. *JAMA Pediatr*. 2021;1(175):525-527.
- Simon TD, Cawthon ML, Stanford S, et al. Pediatric medical complexity algorithm: a new method to stratify children by medical complexity. *Pediatrics*. 2014;133(6):e1647-e1654. doi:10.1542/peds.2013-3875
- Heneghan JA, Goodman DM, Ramgopal S. Demographic and clinical differences between applied definitions of medical complexity. *Hosp Pediatr*. 2022;12(7):654-663.
- Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159. doi:10.2307/2529310
- Feinstein JA, Russell S, DeWitt PE, Feudtner C, Dai D, Bennett TD. R package for pediatric complex chronic condition classification. *JAMA Pediatr*. 2018;172(6):596-598. doi:10.1001/JAMAPEDIATRICS.2018.0256
- Revelle W. Procedures for Psychological, Psychometric, and Personality Research [R package psych version 2.2.9]. Published online September 29, 2022.
- Gorelick MH, Knight S, Alessandrini EA, et al. Lack of agreement in pediatric emergency department discharge diagnoses from clinical and administrative data sources. *Acad Emerg Med*. 2007;14(7):646-652. doi:10.1197/j.aem.2007.03.1357
- Leyenaar JK, Schaefer AP, Freyleue SD, et al. Prevalence of children with medical complexity and associations with health care utilization and in-hospital mortality. *JAMA Pediatr*. 2022;176(6):e220687-e220687. doi:10.1001/jamapediatrics.2022.0687
- Heneghan JA, Goodman DM, Ramgopal S. Variable identification of children with medical complexity in United States PICUs. *Pediatr Crit Care Med*. 2023;24(1):56-61.



38. Ray KN, Shi Z, Ganguli I, Rao A, Orav EJ, Mehrotra A. Trends in pediatric primary care visits among commercially insured US children, 2008–2016. *JAMA Pediatr.* 2020;174(4):350-357.
39. Ames SG, Davis BS, Marin JR, et al. Emergency department pediatric readiness and mortality in critically ill children. *Pediatrics.* 2019;144(3).
40. Ramgopal S, Pelletier JH, Rakkar J, Horvat CM. Forecast modeling to identify changes in pediatric emergency department utilization during the COVID-19 pandemic. *The American Journal of Emergency Medicine.* 2021;49:142-147. doi:10.1016/j.ajem.2021.05.047
41. Ray KN, Olson LM, Edgerton EA, et al. Access to High Pediatric-Readiness Emergency Care in the United States. *The Journal of Pediatrics.* 2018;194:225-232.e1. doi:10.1016/j.jpeds.2017.10.074

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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