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METHODS ARTICLE

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Measuring complications of serious pediatric emergencies using ICD-10

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Abstract

Objective: To create definitions for complications for 16 serious pediatric conditions using the International Classification of Diseases, 10th Revision, Clinical Modification or Procedure Coding System (ICD-10-CM/PCS), and to assess whether complication rates are similar to those measured with ICD-9-CM/PCS.

Data Sources: The Healthcare Cost and Utilization Project State Emergency Department and Inpatient Databases from five states between 2014 and 2017 were used to identify cases and assess complication rates. Incidences were calculated using population counts from the 5-year American Community Survey.

Data Collection/Extraction Methods: Patients were identified by the presence of a diagnosis code for one of the 16 serious conditions. Only the first encounter for a given condition by a patient was included. Encounters resulting in transfer were excluded as the presence of complications was unknown.

Study Design: We defined complications using data elements routinely available in administrative databases including ICD-10-CM/PCS codes. The definitions were adapted from ICD-9-CM/PCS using general equivalence mappings and refined using consensus opinion. We included 16 serious conditions: appendicitis, bacterial meningitis, compartment syndrome, new-onset diabetic ketoacidosis (DKA), ectopic pregnancy, empyema, encephalitis, intussusception, mastoiditis, myocarditis, orbital cellulitis, ovarian torsion, sepsis, septic arthritis, stroke, and testicular torsion. Using data from children under 18 years, we compared incidences and complication rates across the ICD-10-CM/PCS transition for each condition using interrupted time series.

Principal Findings: There were 61 314 ED visits for a serious condition; the most common was appendicitis (n = 37 493). Incidence rates for each condition were not significantly different across the ICD-10-CM/PCS transition for 13/16 conditions. Three differed: empyema (increased 42%), orbital cellulitis (increased 60%), and sepsis (increased 26%). Complication rates were not significantly different for each condition across the ICD-10-CM/PCS transition, except appendicitis (odds ratio 0.62, 95% CI 0.57-0.68), DKA (OR 3.79, 95% CI 1.92-7.50), and orbital cellulitis (OR 0.53, 95% CI 0.30-0.95).

Conclusions: For most conditions, incidences and complication rates were similar before and after the transition to ICD-10-CM/PCS codes, suggesting our system

identifies complications of conditions in administrative data similarly using ICD-9-CM/PCS and ICD-10-CM/PCS codes. This system may be applied to screen for cases with complications and in health services research.

KEYWORDS

administrative data, claims data, complications, outcomes, pediatrics

1 | INTRODUCTION

Efficient diagnosis and management of emergency conditions is a core function of emergency departments (EDs). Understanding and comparing how health systems perform in this role requires accurate measurement of meaningful outcomes such as condition-specific complications. Measuring complications in many health systems is currently challenging as they may not be tracked within institutions; patients may visit more than one hospital through an illness[1]; the most serious conditions and complications are uncommon in children; and there is no consensus on which complications should be measured.

Measuring complications using claims data is appealing because claims are available from many types of health systems, including those without electronic health records.[2-4] Additionally, claims are relatively inexpensive, can track patients between facilities, and allow for ongoing, automated comparative measurement efforts.[5]

We recently developed a method to identify cases of serious pediatric emergency conditions and their complications using claims data coded using the International Classification of Diseases, 9th Revision, Clinical Modification and Procedure Coding System (ICD-9-CM/PCS).[6] However, in October 2015, claims for reimbursement transitioned to ICD-10-CM/PCS, allowing for richer and more precise reports of diagnoses and procedures.[7] Ongoing use of our method would require adaptation to ICD-10-CM/PCS. Accurate translation of ICD-9-CM/PCS codes to ICD-10-CM/PCS is only possible with testing and validation because equivalence mapping frequently introduces inaccuracies that decrease coding accuracy.[8,9] Once translated to ICD-10-CM/PCS, our system could be used in the future to compare complications within and between health systems.

Our objectives were to create definitions for case identification and complications for 16 serious pediatric conditions using ICD-10-CM/PCS, to compare complication rates using data from before and after the transition from ICD-9-CM/PCS to ICD-10-CM/PCS to assess stability, and to compare utilization across the ICD-10-CM/PCS transition.

What is Known on This Topic

- Measuring condition-specific complications of pediatric emergencies is challenging because tracking patients across encounters is difficult.
- There is no standard system for measuring complications using administrative databases.

What This Study Adds

- We created and tested ICD-10 definitions of complications for 16 serious pediatric conditions.
- Children with illness complications had higher resource utilization than those without complications.
- The complications definitions can be applied to most administrative data to allow ascertainment of complication rates.

2 | METHODS

2.1 | Study design and setting

We conducted a cross-sectional study of ED visits in Georgia, Iowa, Maryland, New York, and Wisconsin among children under 18 years. States were selected for their high data quality and reliability (as measured by the percentage of encounters with a valid longitudinal identifier). In 2017, 13.6% of children lived in these states. We used the Healthcare Cost and Utilization Project (HCUP) State ED and Inpatient Databases (collectively, the SDB). The SDB contains information on all ED and inpatient care in those states irrespective of insurance and allows patients to be followed between hospitals. ED encounters appear in the ED or inpatient database depending on whether the encounter resulted in hospitalization.

We included encounters with a diagnosis code of a serious condition, including appendicitis, bacterial meningitis, compartment syndrome, new-onset diabetic ketoacidosis (DKA), ectopic pregnancy, empyema, encephalitis, intussusception, mastoiditis, myocarditis, orbital cellulitis, ovarian torsion, sepsis, septic arthritis, stroke, and testicular torsion. The list of serious conditions was drawn from our prior ICD-9-CM/PCS study, as a goal of the present ICD-10-CM/PCS study was to compare rates to those from ICD-9-CM/PCS (Table 1).[6] The ICD-9-CM/PCS period was 1/1/2014-9/30/2015, and the ICD-10-CM/PCS period was 10/1/2015-12/31/2017 (we did not include data from New York in 2017 because it was not available at the time of manuscript revision).

2.2 | Case identification

Cases were identified using the ICD-9-CM codes we previously defined[6] and the ICD-10-CM codes shown in Table 1. For 10 conditions,

cases were included only if hospitalization occurred, as was the case in our prior ICD-9-CM/PCS study (Table 1).

The ICD-10-CM codes used for case identification were compiled by the authors using the following order of preference: (a) published diagnosis code validity studies; (b) United States studies that used diagnosis codes for case identification; (c) foreign studies that used diagnosis codes for case identification; and (d) the ICD-10-CM codebook.

We excluded transferred patients for whom there were no data from the receiving facility, as we could not determine a final diagnosis or assess the presence of complications. As in the ICD-9-CM/PCS study, we only studied new-onset DKA patients, with new-onset defined by having no previous visits with a diagnosis code for diabetes.

2.3 | Variables

Visit characteristics were obtained from database fields. Visit-level characteristics included patient age (<1, 1-4, 5-7, 8-11, and >11 years), sex, race/ethnicity, and presence of a complex chronic condition (CCC).[10] We assessed the presence of CCCs by determining whether any previous diagnosis of a CCC, as defined by Feudtner et al, appeared in the visit record.[10] CCCs include life-limiting, chronic, and disabling conditions such as malignancies and neuromuscular disorders.

We determined the incidence of each serious condition by dividing the number of cases by the total number of at-risk patient-years. We determined counts of at-risk patient-years by totaling the states' child populations (age < 18 years) for each data year using the American Community Survey.[11] Incidences were calculated separately for the ICD-9-CM/PCS and ICD-10-CM/PCS periods.

2.4 | Outcomes

2.4.1 | Defining complications in ICD-10-CM/PCS

Outcomes included condition-specific complications and utilization measures. We previously used a consensus methodology to define complications using ICD-9-CM/PCS.[6] In that study, the general types of complications were specified for each condition (eg, amputation for compartment syndrome or appendiceal perforation for appendicitis), and these complications were mapped to diagnosis and procedure codes. For instance, bacterial meningitis complications included seizure (defined by the presence of a diagnosis code for seizure) and mechanical ventilation (defined by the presence of a procedure code for intubation or mechanical ventilation). The initial codes were refined through the consensus of several pediatric experts across institutions and specialties.

In this study, we used the same list of complication types for each condition. To define the diagnosis code mappings, we used the same approach as with case identification (see Case Identification above). For procedure code mappings, we began by using the Centers for Medicare and Medicaid Services 2018 General Equivalence Mappings (GEMs) to convert the previous ICD-9-PCS complication-defining codes to ICD-10-PCS codes. Equivalence mappings provide a means of translating between code systems and have been used successfully to monitor condition incidences and outcomes.[12] To be inclusive of complication-defining procedures, we used both the ICD-9-PCS to ICD-10-PCS and ICD-10-PCS to ICD-9-PCS GEMs.

From this initial list, to add specificity, brevity, and consistency for future use of the codes, we dropped any procedure code that did not occur in any patient.

Because ICD-10-CM/PCS includes diagnoses and procedures with no equivalent in ICD-9-CM/PCS, additional ad hoc steps were needed to identify new codes that could define complications. Therefore, the lead author evaluated all co-diagnoses and procedures that occurred in more than 0.25% of index visits for a condition, with this threshold chosen a priori based on feasibility. Finally, the lead author assessed official changes to ICD-10-CM/PCS until the time of manuscript submission for new codes that would obviously define complications. All ad hoc co-diagnoses and procedures that appeared to define a complication were sent to all co-authors who practice medicine for independent voting, with any code receiving more than ≥75% approval being added to the final list of complication-defining ICD-10-CM/PCS codes.

The final list of condition-specific complications was defined using multiple data fields: (a) ICD-9-CM and ICD-10-CM diagnoses, (b) ICD-9-PCS, ICD-10-PCS, or Current Procedural Terminology procedures, (c) and SDB-specific fields such as disposition (eg, discharge to rehabilitation facility, death). Complications were measured at any encounter beginning within 30 days of the index visit.

2.4.2 | Utilization outcomes

To assess the validity of complications definitions, we compared utilization between children with and without complications, before and after the ICD-10-CM/PCS transition. Utilization measures included hospitalization rate (for the index encounter), hospital length of stay (LOS, for those hospitalized), and charges (combining any ED and hospital charges). Hospital LOS and charges were determined for the index encounter, and separately for all encounters starting within 30 days of the index encounter.

2.5 | Analysis

Demographics were reported by condition. For each condition, we determined raw quarterly incidences and plotted incidence trends before and after the ICD-10-CM/PCS transition using Poisson regression. To determine whether there was a change in incidence at the time of the ICD-10-CM/PCS transition, we used interrupted time series analysis for each condition. The regression model used the number of cases as the dependent variable, and time, transition (before or after the ICD-10-CM/PCS transition), and a time-transition

TABLE 1 Definitions of serious conditions included in the study. Diagnosis codes were found in the International Classification of Diseases (Clinical Modification), 10th Revision (ICD-10-CM). Patients were eligible for inclusion only on the first visit for a condition. Definitions of condition-specific complications are shown; patients had a condition-specific complication if they met any of the criteria

Condition[a]	Inclusion criteria[b]	Condition-specific outcomes[c]
Appendicitis[18-21]	K35.x-K37.x	• Diagnosis of appendiceal perforation • Abdominal abscess drainage • Bowel resection • Any diagnosis of sepsis
Bacterial meningitis[22]	A02.21, A32.1x, A39.0, A54.81, G00.x-G01.x *AND* No co-diagnosis of Lyme disease (A69.2x) *AND* Hospitalized or died	• Any diagnosis of seizure • Mechanical ventilation • Any neurosurgery • Discharge to rehabilitation facility • Death
Compartment syndrome	T79.Ax *AND* Hospitalized or died	• Debridement • Amputation
Diabetic ketoacidosis[23]	E10.1x, E11.1x, E13.1x *AND* No previous diagnosis of diabetes (E10.x-E14.x)[24] *AND* Hospitalized or died	• Cerebral edema • Coma • Mechanical ventilation • Discharge to rehabilitation facility • Death
Ectopic pregnancy[25,26]	O00.x	• Laparotomy/laparoscopy • Fallopian operations • Salpingectomy or salpingo-oophorectomy
Empyema[27-29]	J86.x *AND* Hospitalized or died	• Mechanical ventilation • Dialysis • Extracorporeal membrane oxygenation • Cardiopulmonary resuscitation • Any diagnosis of sepsis • Death
Encephalitis[30,31]	A32.12, A39.81, A81.1-A81.2, A83.x-A86, B00.4, B01.11, B02.0, B05.0, B06.01, B26.2, B58.2, G04.81, G04.90, G05.3 *AND* Hospitalized or died	• Any diagnosis of seizure • Mechanical ventilation • Any neurosurgery • Discharge to rehabilitation facility • Death
Intussusception[32,33]	K56.1	• Bowel resection • Intestinal perforation
Mastoiditis[34,35]	H70.x	• Any cranial surgery • Any sinus surgery • Any ear surgery excluding myringotomy • Intracranial venous sinus thrombosis
Myocarditis	A39.52, B33.22, I01.2, I09.0, I40.x-I41.x, I51.4 *AND* Hospitalized or died	• Mechanical ventilation • Dialysis • Extracorporeal membrane oxygenation • Cardiopulmonary resuscitation • Any diagnosis of cardiac arrest • Heart transplant or circulatory support device • Death
Orbital cellulitis[36]	H05.01x-H05.02x *AND* Hospitalized or died	• Any cranial surgery • Any sinus surgery • Any orbital surgery
Ovarian torsion	N83.51x, N83.53x	• Oophorectomy • Salpingectomy • Hysterectomy
Sepsis[15]	Optimized Canadian Institute for Health Information definition[15] *AND* Hospitalized or died	• Mechanical ventilation • Dialysis • Extracorporeal membrane oxygenation • Cardiopulmonary resuscitation • Death

(Continues)

TABLE 1 (Continued)

Condition[a]	Inclusion criteria[b]	Condition-specific outcomes[c]
Septic arthritis[37,38]	M00.x-M01.x *AND* Hospitalized or died	• Any diagnosis of sepsis
Stroke[39-41]	I63.x, I67.81-I67.82 *AND* Hospitalized or died	• Mechanical ventilation • Discharge to rehabilitation facility • Death
Testicular torsion[42]	N44.00-N44.02	• Orchiectomy

[a]References for inclusion diagnosis codes (if they exist) are given in superscript.

[b]Any digit may substitute for x.

[c]Criteria for condition-specific outcomes are shown in Table S1.

interaction term as independent variables. We compared the Poisson incidence estimates for 2015 quarter 3 (the last quarter of ICD-9-CM/PCS) with the estimates immediately following the interruption, in 2015 quarter 4 (the first quarter of ICD-10-CM/PCS) with incidence rate ratios. We did not use a wash in period because the intervention (implementation of ICD-10-CM) occurred abruptly and completely. We considered a significant rate difference ($P < .05$) to indicate a change in incidence attributable to the ICD-10-CM/PCS transition.

We then examined overall complication rates for each condition before and after the ICD-10-CM/PCS transition. Complication rates were calculated per condition as the number of cases with any one or more complication types, divided by the number of cases. Specific complication rates were compared using Fisher's exact tests, and 95% binomial exact confidence intervals were determined. We repeated the interrupted time series analysis with complication rates, this time using logistic regression to create complication trend estimates, with case-level complication status as the dependent variable. We determined the odds ratio of a complication in the quarter after versus the quarter before the ICD-10-CM/PCS transition. We considered complication rate changes to be attributable to the ICD-10-CM/PCS transition if the odds ratio was significantly different from 1.

After the complications analysis, we noticed a major change in complication rates for appendicitis around the ICD-10-CM/PCS transition. We hypothesized that this was because of insufficiently granular diagnosis codes for perforated appendicitis, as clinicians would likely use ICD-10-CM code K35.3 (appendicitis with localized peritonitis) for perforated appendicitis in a considerable fraction of cases. Therefore, we conducted a post hoc exploratory analysis to assess whether classifying K35.3 as perforated appendicitis could explain the lower complication rates observed after the ICD-10-CM/PCS transition. We recreated the actual rates and trend estimates after reclassifying K35.3 as a complication, and a separate rate curve using the mean rates between the original and reclassified proportions.

We then examined resource utilization by condition and compared whether resource utilization differed in uncomplicated and complicated patients across the ICD-10-CM/PCS transition. Total charges and hospital LOS were reported using medians and interquartile ranges (IQR); hospitalization rates were reported using proportions. Patients who died on the index encounter were excluded from these calculations, as they frequently had very little resource utilization. To determine whether condition-specific median hospital LOS or charges differed across the ICD-10-CM/PCS transition, we used separate univariable median regressions with bootstrapped 95% confidence intervals and p values for each condition.

Data were analyzed using R version 3.6.1 (R Foundation, Vienna, Austria). We defined significance as a two-tailed $P < .05$. The Institutional Review Board deemed this study exempt from review. Small observation counts between 1 and 10 were censored in accordance with HCUP data use requirements.

3 | RESULTS

The final consensus and evidence-based ICD-10-CM/PCS codes for case identification are shown in Table 1. The final codes for identifying complications of conditions after applying GEMs, removing procedures that never occurred, and manual additions are presented in Table S1. The manual additions included new procedure codes for extracorporeal membrane oxygenation and new, more specific diagnosis codes for perforated appendicitis to replace K35.2 (appendicitis with generalized peritonitis) and K35.3 (appendicitis with localized peritonitis).

Our patient-level data source, the HCUP SDB, covered 36.2 million child-years of follow-up. We analyzed 61 314 encounters among 59 921 patients after dropping 4439 (6.8%) encounters because there was no information from the receiving hospital after a transfer. Demographic characteristics of the study population by condition are shown in Table S2.

Myocarditis had the lowest condition-specific incidence, with 6.3 cases per million person-years in the ICD-9-CM/PCS period and 5.7 in the ICD-10-CM/PCS period. Appendicitis was the most common condition, with 1050 cases per million person-years in the ICD-9-CM/PCS period and 1020 in the ICD-10-CM/PCS period. The condition-specific incidence changed at the ICD-10-CM/PCS transition for 3 of the 16 analyzed conditions: empyema (incidence increase of 42%, 95% CI 2-97, $P = .04$), orbital cellulitis (increase of 60%, 95% CI 26-103, $P < .001$), and sepsis (increase of 26%, 95% CI

17-36, $P < .001$). There was no discernable difference in incidences for the other conditions (Figure 1).

Complications occurred in fewer than 10% of patients in three conditions both before and after the ICD-10-CM/PCS transition: new-onset diabetic ketoacidosis, intussusception, and septic arthritis. Complications occurred in more than half of patients both before and after the transition in encephalitis and ovarian torsion. Specific complication subtype rates are presented in Table S3. Using interrupted time series analysis, complication rates were similar around the ICD-10-CM/PCS transition for all conditions except appendicitis (odds ratio [OR] for complications 0.62, 95% CI 0.57-0.68, $P < .001$), new-onset DKA (OR 3.79, 95% CI 1.92-7.50, $P < .001$), and orbital cellulitis (OR 0.53, 95% CI 0.30-0.95, $P = .03$) (Figure 2). The exploratory analysis for appendicitis revealed that including ICD-10-CM code K35.3 as a complication would have increased complication rates significantly after the ICD-10-CM/PCS transition (OR 1.22, 95% CI 1.12-1.32) (Figure S1). Complication rates would not have been different before and after the ICD-10-CM/PCS transition if half of K35.3 cases had been classified as perforation ($P = .09$).

Resource utilization was higher in complicated patients compared with uncomplicated patients within each condition and diagnosis coding system, as measured by length of stay and charges (Figure 3). Median index visit lengths of stay ranged from 0 days (uncomplicated testicular torsion) to 19 days (complicated bacterial meningitis and sepsis). Median index visit charges ranged from $2840 (uncomplicated ectopic pregnancy) to $229 860 (complicated myocarditis). Median lengths of stay and charges were similar between the ICD-9-CM/PCS and ICD-10-CM/PCS periods for most conditions. Exceptions included appendicitis charges and lengths of stay (higher during the ICD-10-CM/PCS period for both uncomplicated and complicated patients); charges for uncomplicated DKA (higher during ICD-10-CM/PCS) and complicated DKA (lower during

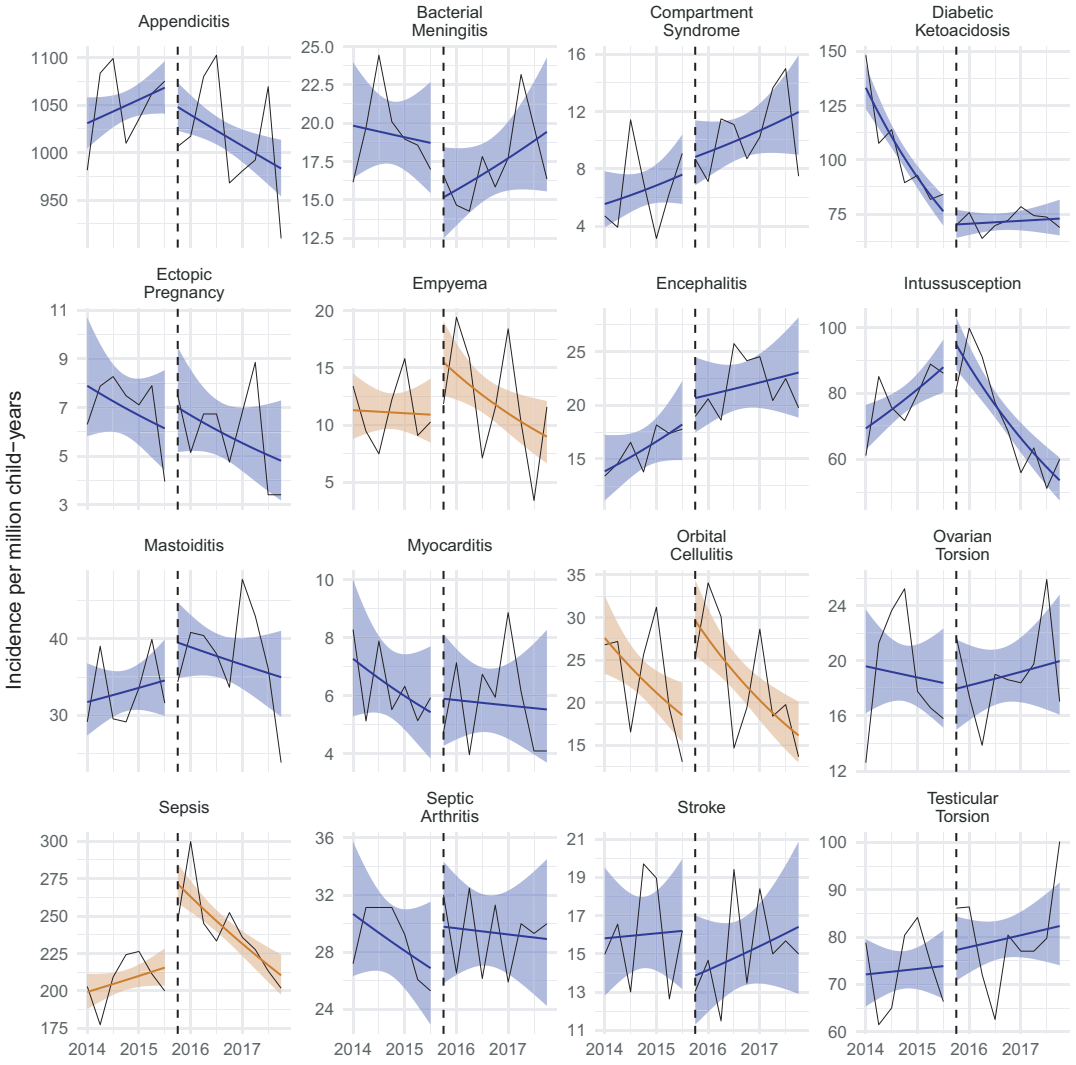

FIGURE 1 Quarterly incidence rates (per million child-years) for 16 serious acute pediatric conditions around the International Classification of Diseases, 10th Revision, Clinical Modification/Procedure Coding System (ICD-10-CM/PCS) transition in October 2015 (dashed line). Actual rates are shown in black. Fitted Poisson regression estimates and 95% confidence intervals are shown in color. There was a significant difference ($P < .05$) between the incidence estimates in the quarter before and after the ICD-10-CM/PCS transition for those in orange, and there was no significant difference for those in blue [Color figure can be viewed at wileyonlinelibrary.com]

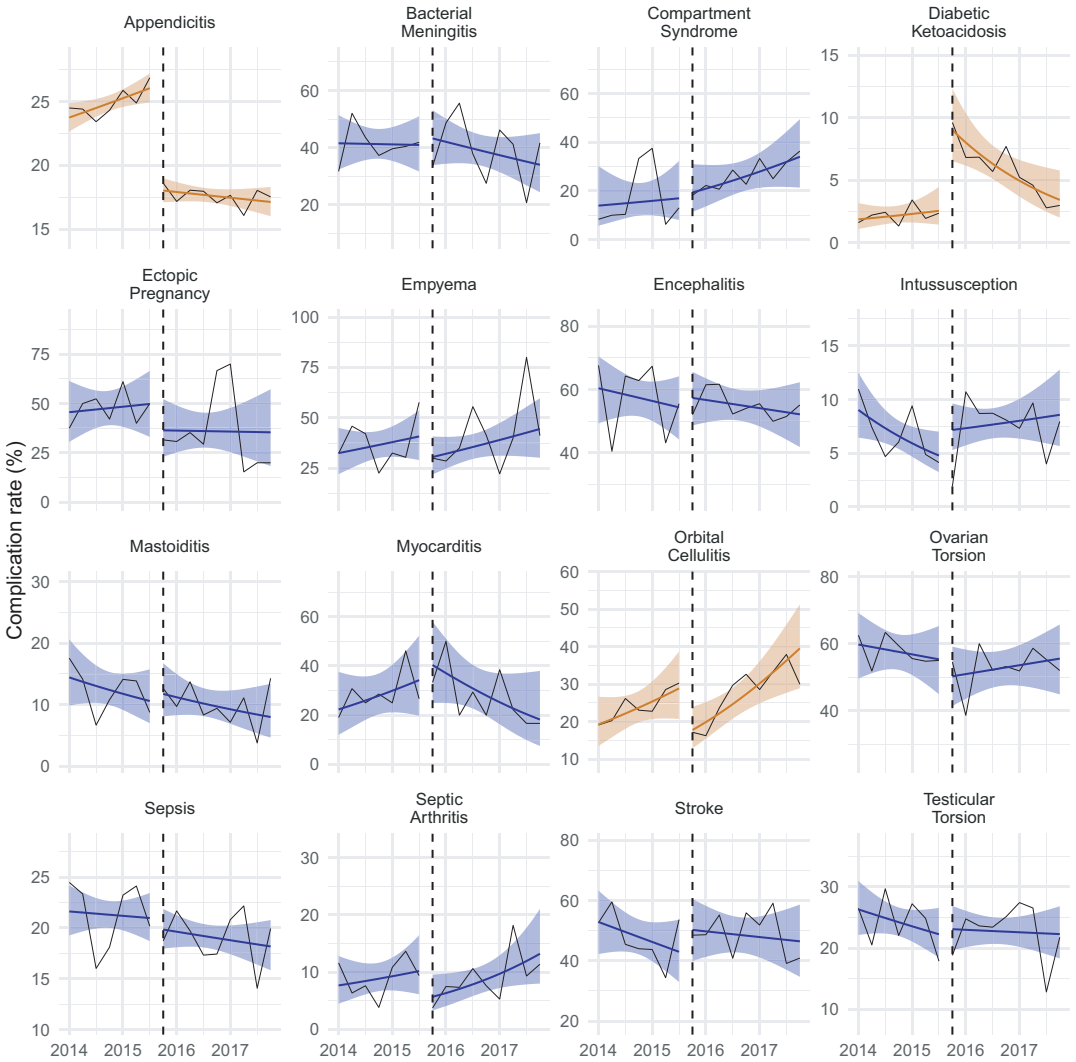

FIGURE 2 Quarterly complication rates (per million child-years) for 16 serious acute pediatric conditions around International Classification of Diseases, 10th Revision, Clinical Modification/Procedure Coding System (ICD-10-CM/PCS) transition in October 2015 (dashed line). Actual rates are shown in black. Fitted logistic regression estimates and 95% confidence intervals are shown in color. There was a significant difference ($P < .05$) between the complication estimates in the quarter before and after the ICD-10-CM/PCS transition for those in orange, and there was no significant difference for those in blue [Color figure can be viewed at wileyonlinelibrary.com]

ICD-10-CM/PCS); charges for uncomplicated orbital cellulitis (higher during ICD-10-CM/PCS); charges for complicated ovarian torsion (higher during ICD-10-CM/PCS); lengths of stay for uncomplicated stroke (slightly shorter during ICD-10-CM/PCS); and charges for uncomplicated and for complicated testicular torsion (higher during ICD-10-CM/PCS).

4 | DISCUSSION

We extended a method for identifying complications of serious pediatric emergencies from the ICD-9-CM/PCS coding system to ICD-10-CM/PCS. For most conditions, the incidence, complication rates, and resource utilization were similar before and after the ICD-10-CM/PCS transition. This study extends our previous work establishing definitions of complications using the ICD-9-CM/PCS coding system, allowing for comparison of rates and trends of complications through the present day.

While we did not establish the validity of the method through direct case review, we did demonstrate the validity through several other means. First, there was face validity in the use of GEMs to create the codes, followed by a consensus expert review. That is considered the most robust process for code translation.[7,13] Second, there was convergent validity in that incidences and complications were mostly stable across the transition. Third, patients identified as having complications had higher resource utilization than those without, suggesting they truly had a more complicated course. Fourth, patients with complications had similar resource utilization in most cases when comparing the ICD-9-CM/PCS period to the ICD-10-CM/PCS period.

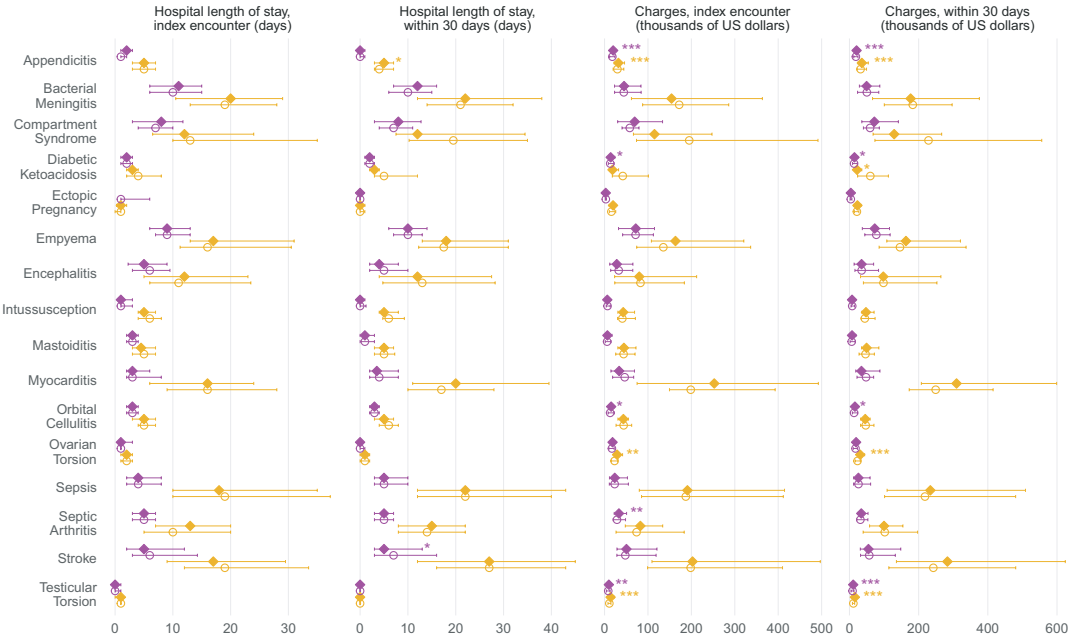

FIGURE 3 Resource utilization by condition for those with complications (goldenrod) and without (purple), and for encounters occurring during the International Classification of Diseases, 9th Revision, Clinical Modification/Procedure Coding System (ICD-9-CM/PCS) period (filled diamonds) or ICD-10-CM/PCS period (open circles). For each measure, the median and 25th-75th percentile ranges are shown. Asterisks indicate significant differences in median between ICD-9-CM/PCS and ICD-10-CM/PCS estimates: none: $P \geq .05$, *: $P < .05$, **: $P < .01$: ***, $P < .001$ [Color figure can be viewed at wileyonlinelibrary.com]

Assessing whether incidence measurements changed across the ICD-10-CM/PCS transition answers the question of whether ICD-10-CM codes identify similar cases as ICD-9-CM.[12] The incidence measurably changed across the ICD-10-CM/PCS transition for only 3 of the 16 included conditions: empyema, orbital cellulitis, and sepsis. It is unclear why ascertainment changed for empyema, as the codes used in ICD-9-CM are analogous to those in ICD-10-CM. In the case of orbital cellulitis, there were no distinct periorbital cellulitis diagnosis codes in ICD-10-CM until 2017 (L03.213), likely inflating the orbital cellulitis incidence for the 5 quarters before those codes came into use. This theory is buttressed by the steeply decreasing incidence of orbital cellulitis and increasing complication rate through the ICD-10-CM/PCS period. Finally, sepsis is a complicated condition to identify. However, unlike for most of the other conditions, others have undertaken deep efforts to create code-based identification systems for sepsis that have been shown to have good specificity.[14,15]

Determining how complication rates changed across the ICD-10-CM/PCS transition answers the question of whether ICD-10-CM/PCS codes identify complications similarly to ICD-9-CM/PCS. Rates changed measurably for only 3 of the 16 conditions: appendicitis, DKA, and orbital cellulitis. Complication rates for appendicitis went down significantly almost certainly because of a lack of specific diagnosis codes for appendiceal perforation in ICD-10-CM. This is reflected in our exploratory analysis of appendicitis codes, which showed that if roughly half of "localized peritonitis" cases had appendiceal perforation, complication rates would have been similar between ICD-9-CM and ICD-10-CM. New ICD-10-CM codes that clearly define perforated appendicitis became available starting in 2019 and are included in our code set. However, using our system to measure complications for appendicitis should be approached cautiously from October 2015 through 2019. For DKA, complication rates went up largely because of higher rates of coma. Coma was almost never identified in ICD-9-CM and is likely undercounted in ICD-9-CM based on previous clinical work on complication rates in DKA.[16,17] Finally, orbital cellulitis complication rates likely went down after ICD-10-CM/PCS implementation because of the aforementioned likely inclusion of periorbital cellulitis cases until a separate periorbital cellulitis diagnosis code became available.

Our system for identifying condition-specific complications may be useful in several ways. First, complication rates may be compared between health systems, regions, or between hospitals with high pediatric volume. Second, research may be conducted on factors leading to complications. Third, quality improvement leaders can use the definitions to screen cases for review to determine whether complications were preventable. Finally, our approach for creating complications definitions can be applied to other acute conditions, including outside of pediatrics. The importance of this system is that many important and serious pediatric acute conditions are insufficiently common to allow for measurement of complications using clinical data alone.

There are several limitations to this work. GEMs mappings ceased to be available after 2018. Future changes to diagnosis and procedure codes will not be mappable to ICD-9-CM/PCS. As is true of all research using administrative data, as code sets evolve,

researchers will need to be mindful of coding changes. We anticipate updating this system in the future as codes change, but have incorporated the latest coding changes through 2020 (for instance, new codes for extracorporeal membrane oxygenation and appendiceal perforation). A major limitation of studies using only administrative data is the inability to confirm cases and outcomes directly; our system has not been validated through direct review of health records. Assessment of this system using direct comparisons with patient records would add additional validity; this research is planned. Finally, we recommend caution applying this system for the period following directly after the ICD-10-CM/PCS transition for appendicitis and orbital cellulitis, because of code ambiguity that has since been rectified.

5 | CONCLUSION

We extended a system using the ICD-9-CM/PCS system to identify complications of serious conditions to ICD-10-CM/PCS. Researchers and quality improvement specialists may use this system to screen cases for complications or measure complication rates. Validation of the system using chart reviews is a key next step.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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