Complications of Serious Pediatric Conditions in the Emergency Department: Definitions, Prevalence, and Resource Utilization

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Objectives To define and measure complications across a broad set of acute pediatric conditions in emergency departments using administrative data, and to assess the validity of these definitions by comparing resource utilization between children with and without complications.

Study design Using local consensus, we predefined complications for 16 acute conditions including appendicitis, diabetic ketoacidosis, ovarian torsion, stroke, testicular torsion, and 11 others. We studied patients under age 18 years using 3 data years from the Healthcare Cost and Utilization Project Statewide Databases of Maryland and New York. We measured complications by condition. Resource utilization was compared between patients with and without complications, including hospital length of stay, and charges.

Results We analyzed 27 087 emergency department visits for a serious condition. The most common was appendicitis (n = 16 794), with 24.3% of cases complicated by 1 or more of perforation (24.1%), abscess drainage (2.8%), bowel resection (0.3%), or sepsis (0.9%). Sepsis had the highest mortality (5.0%). Children with complications had higher resource utilization: condition-specific length of stay was longer when complications were present, except ovarian and testicular torsion. Hospital charges were higher among children with complications ($P < .05$) for 15 of 16 conditions, with a difference in medians from $3108 (testicular torsion) to $13 7694 (stroke).

Conclusions Clinically meaningful complications were measurable and were associated with increased resource utilization. Complication rates determined using administrative data may be used to compare outcomes and improve healthcare delivery for children. *(J Pediatr 2019;214:103-12)*.

Timely evaluation, stabilization, and optimal management of serious emergency conditions are major goals of emergency departments (EDs). For serious conditions such as sepsis and appendicitis, timely and effective management reduces the risk of complications and morbidity.[1-4] Measuring complications across a broad set of clinicians and institutions would provide a means to compare health system performance, determine risk factors for poor outcomes, and direct efforts toward appropriate resource allocation for the highest-risk conditions.

Most serious conditions in children are uncommon, which makes precise measurement of complication rates challenging.[5] Infrastructure for research and quality measurement varies considerably between institutions.[6] Infrastructure to measure and report care quality is less common in rural and nonacademic centers; thus, most current understanding of complication rates is based on data from urban, academic centers, which may not reflect outcomes nationally.[7-9] Measuring outcomes and complications of illness is also challenging when patients visit more than 1 institution in an illness episode, as patients may be lost to follow-up.[10] Population-based claims databases provide a means to measure the outcomes from EDs of all types and in illness episodes spanning multiple institutions.[11] Such approaches overcome the limitations of traditional clinical data measurement that rely on collection of clinical data from small cohorts of patients and institutions.

To measure complications of illness using claims data, definitions of complications would need to be developed based on the diagnoses, procedures, and resources utilized. Currently, a concise, usable, and validated list of condition-specific complications measurable in claims data does not exist.

Our objective was to define a list of condition-specific, short-term complications measurable from claims data across a set of serious pediatric emergency diagnoses, without respect to preventability. To focus our investigation, we selected serious pediatric conditions that might be sensitive to the timeliness of diagnosis. We then measured complications across EDs in 2 states

CCC	Complex chronic condition
ED	Emergency department
ICD-9	*International Classification of Diseases, 9th Revision*
ICD-10	*International Classification of Diseases, 10th Revision*
LOS	Length of stay
SDB	Statewide emergency department and inpatient database

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and compared resource utilization between children with and without complications of illness to provide evidence of the validity of complication definitions.

Methods

We conducted a population-based cohort study of ED visits in 2 states among children under age 18 years. We used the Healthcare Cost and Utilization Project Statewide Emergency Department Databases and Statewide Inpatient Databases (collectively SDBs) of Maryland (January 2013-Septemeber 2015) and New York (January 2011-September 2013). In each state, visits from October-December were not included to allow for accurate assessment of post-visit utilization outcomes during those months. The SDBs capture all statewide ED visits and include standardized demographic, disposition, diagnosis, and charge information as billed at the time of the encounter. The SDBs also include identifiers to allow tracking patients between different ED visits and facilities.[12] The 2 states have a population of 5.6 million children who are geographically, racially, and ethnically, diverse.[13]

We analyzed each patient's earliest ED visit with a diagnosis of a serious condition (Table I). These conditions were selected to represent a spectrum of severity, frequency, and complexity of diagnoses in which optimal emergency care reduces the risk of complications, known as emergency-sensitive conditions. Because no consensus list of such conditions exists for children, we adapted a list intended for adults.[49] Diagnoses that, in children, are extremely rare (such as myocardial infarction) or poorly defined (such as other disorders of the brain) were removed. We added conditions we believed to be sensitive to delays in diagnosis among children (such as intussusception or new-onset diabetic ketoacidosis). We decided not to include conditions that are important and serious but for which diagnosis codes lack specificity for case identification (such as pneumonia).[50] Our list was not intended to be comprehensive, but rather represented a sample of conditions that would likely be emergency sensitive in children. From the initial list of conditions, we excluded any with fewer than 104 ED visits during the study period. This number was needed to achieve 95% CIs no greater than 10 percentage points away from the complication rate estimate.

Selection of Participants

Cases were identified using *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) diagnosis codes used previously in code validation studies or for case-finding (Table I). For certain conditions, children are uniformly hospitalized; we identified such conditions as those with hospitalization rates >80% (eg, sepsis). For the 10 such conditions, listed in Table I as requiring hospitalization to meet the case definition, we excluded from analysis children who were coded as not being hospitalized to improve the specificity of case identification. For patients with diabetic ketoacidosis, we were most interested in new presentations of diabetes in which diagnosis is more challenging, so we included only patients with no prior diagnosis of any diabetic condition (ICD-9 250.1x) in the SDB.

The same patient could appear in the study more than once if they had more than 1 study condition. We only included the earliest visit for a particular condition so as not to erroneously identify visits for complications as index visits. 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.

Variables

Visit characteristics were obtained from database fields. If 1 or more transfers occurred, ED characteristics were determined from the final ED, as we assumed that is where definitive care occurred. ED-level characteristics included Maryland or New York location and urban-rural location. Visit-level characteristics included patient age (<1, 1-4, 5-7, 8-11, and >11 years), sex, race, ethnicity, socioeconomic status, and presence of a complex chronic condition (CCC).[51] To assess socioeconomic status, we used the quartile of median income for the patient's zip code.[52] We assessed the presence of CCCs by determining whether any diagnosis of a CCC, as defined by Feudtner et al, appeared in the SDBs at an earlier visit for a given patient.[51] CCCs include serious, chronic, and disabling conditions such as malignancies and neuromuscular disorders.

We determined the incidence of each serious condition by dividing the number of first-time cases by the total number of at-risk child-years. At-risk child-years were determined by totaling the states' child populations (age <18 years of age) for each data year using the national census.[13] We subtracted 25% from the final data year for each state because we did not include the final 3 months of visits.

Outcomes

Outcomes included condition-specific complications and utilization measures. Complications were defined prior to data analysis by review of the evidence base and by consensus among the study investigators (references to evidence shown in Table I). To develop the condition-specific complication definitions, 2 investigators first developed a general outline of the types of outcomes complicating each condition; for instance, perforation is a known complication of appendicitis; seizures are known to complicate bacterial meningitis. Complications included procedures that are frequently indicated but represent a complicated course of disease, such as surgical treatment of ectopic pregnancy, or orchiectomy instead of testicular detorsion in testicular torsion. Complications were chosen without regard to preventability, as our goal was to identify outcomes that patients would view as a worse course of illness than in uncomplicated cases. Next, the lead author specified the diagnosis, procedure, and disposition codes that mapped to each outcome. To be as inclusive of complicated outcomes as possible, we generated a list of all procedures performed

Table 1. Definitions of serious conditions included in the study, arranged in descending order of incidence

Condition*	Inclusion Criteria†	Condition-specific Outcomes	Outcome-defining Diagnosis and Procedure Codes‡
Appendicitis[2,4,14,15]	ICD-9 540-542	- Diagnosis of appendiceal perforation - Abdominal abscess drainage - Bowel resection - Any diagnosis of sepsis	- ICD-9 diagnosis 540.0-1 - ICD-9 47.2, 54.91, 97.82 or CPT 44900 - ICD-9 17.31-39, 45.61-83, 46.02 - ICD-9 diagnosis 785.52, 995.91-92
Sepsis[16]	ICD-9 785.52, 995.91-92 *AND* Hospitalized or died	- Mechanical ventilation - Dialysis - ECMO - Cardiopulmonary resuscitation - Death	- ICD-9 31.1, 96.04, 96.70-72 or CPT 31500 - ICD-9 39.95, 54.98 - ICD-9 39.65-66 - ICD-9 99.60, 99.63 or CPT 92950
Diabetic ketoacidosis[17–19]	ICD-9 250.1x *AND* No previous diagnosis of diabetes (250.xx) *AND* Hospitalized or died	- Cerebral edema - Coma - Mechanical ventilation - Discharge to rehabilitation facility - Death	- ICD-9 diagnosis 348.5 - ICD-9 diagnosis 250.3x or 780.01 - ICD-9 31.1, 31.42, 96.04, 96.70-72 or CPT 31500
Intussusception[20–23]	ICD-9 560.0	- Bowel resection - Intestinal perforation	- ICD-9 17.31-39, 45.41, 45.61-83, 46.02 - ICD-9 diagnosis 569.83
Testicular torsion[24,25]	ICD-9 608.20	- Orchiectomy	- ICD-9 62.3-63.42, 63.72 or CPT 54520-54522, 54690
Orbital cellulitis[26–28]	ICD-9 376.01-02 *AND* Hospitalized or died	- Any cranial surgery - Any sinus surgery - Any orbital surgery	- ICD-9 1.21, 1.24-25, 1.31-2.01, 2.06-07, 2.12, 2.21-41, 2.92, 2.99 - ICD-9 22.00-9 - ICD-9 16.01-09, 16.22-59, 16.92-99
Mastoiditis[29,30]	ICD-9 383.00-02, 383.9	- Any cranial surgery - Any sinus surgery - Any ear surgery excluding myringotomy - Intracranial venous sinus thrombosis	- ICD-9 1.21, 1.24-25, 1.31-2.99 - ICD-9 18.21, 22.00-9 - ICD-9 19.0-9, 20.21-23, 20.41-49, 20.59-62 20.79 - ICD ICD-9 diagnosis 437.5
Septic arthritis[31]	ICD-9 711.0x *AND* Hospitalized or died	- Any diagnosis of sepsis	- ICD-9 diagnosis 785.52, 995.91-92
Ovarian torsion[32,33]	ICD-9 620.5	- Oophorectomy - Salpingectomy - Hysterectomy	- ICD-9 65.24-49 or CPT 58661, 58720, 58920, 58940 - ICD-9 66.4-66.69, 66.92 or CPT 58700 - ICD-9 68.31-79, 68.9, or CPT 58150
Bacterial meningitis[34,35]	ICD-9 320.x *AND* No co-diagnosis of Lyme disease (088.81) *AND* Hospitalized or died	- Any diagnosis of seizure - Mechanical ventilation - Any neurosurgery - Discharge to rehabilitation facility - Death	- ICD-9 diagnosis 345.x, 780.3x - See sepsis - ICD-9 1.10, 1.24-26, 1.39, 1.52-59, 2.21-34, 2.39, 2.42-43
Empyema[36,37]	ICD-9 510.x *AND* Hospitalized or died	- Mechanical ventilation - Dialysis - ECMO - Cardiopulmonary resuscitation - Death - Any diagnosis of sepsis	- See sepsis
Stroke[38,39]	ICD-9 433.x1, 434.x1, 437.1 *AND* Hospitalized or died	- Mechanical ventilation - Discharge to rehabilitation facility - Death	- ICD-9 31.1, 31.42, 96.04, 96.70-72 or CPT 31500
Encephalitis[40–44]	ICD-9 323.01, 323.41, 323.81, 323.9 *AND* Hospitalized or died	- Any diagnosis of seizure - Mechanical ventilation - Any neurosurgery - Discharge to rehabilitation facility - Death	- See bacterial meningitis
Ectopic pregnancy[45]	ICD-9 633.x0	- Laparotomy/laparoscopy - Fallopian operations - Salpingectomy or salpingo-oophorectomy	- ICD-9 54.19-21 or CPT 49999 - ICD-9 66.01-02, 66.71-79, 66.99, 74.2 or CPT 59121, 59130, 59150 - ICD-9 66.22-69, 66.92 or CPT 58679-58700, 59120, 59135-6, 59151

(*continued*)

Table 1. Continued

Condition*	Inclusion Criteria†	Condition-specific Outcomes	Outcome-defining Diagnosis and Procedure Codes‡
Myocarditis[46,47]	ICD-9 074.23, 422.0, 422.90, 422.91, 422.99 *AND* Hospitalized or died	- Mechanical ventilation - Dialysis - ECMO - CPR - Any diagnosis of cardiac arrest - Heart transplant or circulatory support device - Death	- ICD-9 31.1, 96.04, 96.70-72 or CPT 31500 - ICD-9 39.95, 54.98 - ICD-9 39.65-66 - ICD-9 99.60, 99.63 or CPT 92950 - ICD-9 diagnosis 427.41, 427.5 - ICD-9 37.51-68 or CPT 92950
Compartment syndrome[48]	ICD-9 958.90-92 *AND* Hospitalized or died	- Debridement - Amputation	- 83.32-39, 83.44-49 - ICD-9 84.00-19, 84.91

CPR, cardiopulmonary resuscitation; *CPT*, Current Procedural Terminology; *ECMO*, extracorporeal membrane oxygenation.
Diagnosis codes were found in the International Classification of Diseases (Clinical Modification), 9th Revision (ICD-9). 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.
*References for types of complications are given in superscript.
†All codes are ICD-9 diagnosis codes. Any digit may substitute for x.
‡Codes are procedure codes unless otherwise specified. Any digit may substitute for x.

during ED visits for each condition; procedures missed in our initial mapping were added to the list of complication-defining codes. Once the draft list of specific diagnosis, procedure, and disposition codes was developed, it was reviewed by each study author individually, and 1 additional external reviewer. These comprised 4 academic pediatric emergency medicine physicians and 1 academic pediatrician and safety expert across three institutions. All were blinded to the rates of complications that the chosen procedures would identify. To make the final complications definitions as specific as possible, procedures without unanimous approval were removed from the list of outcomes.

Condition-specific outcomes were specified using multiple data fields: (1) ICD-9 diagnoses at or after the index visit, (2) ICD-9 or Current Procedural Terminology procedures performed during or after the index visit, (3) and SDB-specific fields such as disposition.

To assess the validity of complications definitions, we compared utilization between children with and without complications. Utilization measures included hospitalization rate (for the index visit), 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. For each condition, we also determined the median number of encounters within 30 days of the index encounter, and cumulative revisit rates from 1 to 90 days after index discharge, stratified by whether a complication occurred. Revisits were defined as a visit to an ED or hospitalization after the index discharge.

Analyses

Demographics were reported by condition. Condition-specific outcomes were included if they occurred during the index encounter. Encounters that ended after the 30-day window were included in the calculation, but were uncommon, comprising 2.2% of encounters. We reported condition-specific outcome rates using proportions and binomial exact 95% CIs.

Total charges and hospital LOS were reported using medians and IQR; hospitalization rates were reported using proportions. Patients who died on the index encounters were excluded from these calculations, as they frequently had very little resource utilization. To determine whether condition-specific median hospital LOS or charges differed between patients with and without complications, we used separate univariable median regressions with bootstrapped 95% CIs and *P* values for each condition. Differences in hospitalization rates were determined using the Fisher exact test. *P* values with a 2-sided alpha of 0.05 were considered significant.

Data were analyzed using R v 3.5.0 (R Foundation, Vienna, Austria). The Institutional Review Board deemed this study exempt from review. Small observation counts between 1 and 10 were censored in accordance with Healthcare Cost and Utilization Project data use requirements.

Results

Consensus definitions for case identification, previous literature guiding outcomes definitions, and final definitions of outcomes for the 16 analyzed conditions are shown in Table I. There were 5.7 million child ED visits among 2.7 million unique patients seen during the study period. We included 29 103 index visits (0.5% of all statewide pediatric visits) for serious conditions, among 28 580 unique patients. We planned on analyzing the following conditions totaling 261 visits, but excluded them for failing to meet our prespecified power criterion of 104 visits: cranial or spinal abscess (n = 102), pulmonary embolism (95), necrotizing fasciitis (54), and cranial venous sinus thrombosis (10). We also excluded 2015 visits (6.9%) because of transfer to another hospital with no available

Table III. Frequency of complications by serious condition

Conditions (N)	Complication	Frequency, n (%, 95% CI)
Appendicitis (16 794)	Any complication	4088 (24.3, 23.7-25.0)
	- Appendiceal perforation	4049 (24.1, 23.5-24.8)
	- Abdominal abscess drainage	462 (2.8, 2.5-3.0)
	- Bowel resection	46 (0.3, 0.2-0.4)
	- Sepsis	145 (0.9, 0.7-1.0)
Sepsis (2808)	Any complication	631 (22.5, 20.9-24.1)
	- Mechanical ventilation	592 (21.1, 19.6-22.6)
	- Dialysis	43 (1.5, 1.1-2.1)
	- ECMO	23 (0.8, 0.5-1.2)
	- Cardiopulmonary resuscitation	54 (1.9, 1.4-2.5)
	- Death	140 (5.0, 4.2-5.9)
Diabetic ketoacidosis (1504)	Any complication	18 (1.2, 0.7-1.9)
	- Cerebral edema	11 (0.7, 0.4-1.3)
	- Coma	0 (0.0, 0.0-0.2)
	- Mechanical ventilation	*
	- Discharge to rehabilitation facility	*
	- Death	*
Intussusception (1257)	Any complication	74 (5.9, 4.7-7.3)
	- Bowel resection	74 (5.9, 4.7-7.3)
	- Intestinal perforation	*
Testicular torsion (956)	Orchiectomy	193 (20.2, 17.7-22.9)
Orbital cellulitis (692)	Any complication	88 (12.1, 9.8-14.8)
	- Any cranial surgery	*
	- Any sinus surgery	68 (9.8, 7.7-12.3)
	- Any orbital surgery	54 (7.8, 5.9-10.1)
Mastoiditis (644)	Any complication	55 (8.5, 6.5-11.0)
	- Any cranial surgery	*
	- Any sinus surgery	*
	- Any ear surgery excluding myringotomy	48 (7.5, 5.5-9.8)
	- Intracranial venous sinus thrombosis	0 (0.0, 0.0-0.6)
Septic arthritis (458)	Any diagnosis of sepsis	42 (9.2, 6.7-12.2)
Ovarian torsion (329)	Any complication	194 (59.0, 53.4-64.3)
	- Oophorectomy	172 (52.3, 46.7-57.8)
	- Salpingectomy	32 (9.7, 6.7-13.5)
	- Hysterectomy	0 (0.0, 0.0-1.1)
Bacterial meningitis (323)	Any complication	118 (36.5, 31.3-42.0)
	- Any diagnosis of seizure	58 (18.6, 14.5-23.3)
	- Mechanical ventilation	48 (14.9, 11.2-19.2)
	- Any neurosurgery	60 (18.6, 14.5-23.3)
	- Discharge to rehabilitation facility	12 (3.7, 1.9-6.4)
	- Death	*
Empyema (252)	Any complication	79 (31.3, 25.7-37.5)
	- Mechanical ventilation	50 (19.8, 15.1-25.3)
	- Dialysis	*
	- ECMO	*
	- Cardiopulmonary resuscitation	*
	- Death	*
	- Any diagnosis of sepsis	49 (19.4, 14.7-24.9)
Stroke (226)	Any complication	112 (49.6, 42.9-56.3)
	- Mechanical ventilation	93 (41.2, 34.7-47.9)
	- Discharge to rehabilitation facility	46 (20.4, 15.3-26.2)
	- Death	19 (8.4, 5.1-12.8)
Encephalitis (159)	Any complication	83 (52.2, 44.2-60.2)
	- Any diagnosis of seizure	66 (41.5, 33.8-49.6)
	- Mechanical ventilation	32 (20.1, 14.2-27.2)
	- Any neurosurgery	11 (6.9, 3.5-12.0)
	- Discharge to rehabilitation facility	17 (10.7, 6.4-16.6)
	- Death	*
Ectopic pregnancy (151)	Any complication	70 (46.4, 38.2-54.6)
	- Laparotomy/laparoscopy	17 (11.3, 6.7-17.4)
	- Fallopian operations	*
	- Salpingectomy or salpingo-oophorectomy	60 (39.7, 31.9-48.0)
Myocarditis (142)	Any complication	30 (21.1, 14.7-28.8)
	- Mechanical ventilation	27 (19.0, 12.9-26.4)
	- Dialysis	*
	- ECMO	*
	- CPR	*
	- Any diagnosis of cardiac arrest	*
	- Heart transplant or circulatory support device	*
	- Death	*

(*continued*)

Table III. Continued

Conditions (N)	Complication	Frequency, n (%, 95% CI)
Compartment syndrome (132)	Any complication	25 (18.9, 12.6-26.7)
	- Debridement	25 (18.9, 12.6-26.7)
	- Amputation	0 (0.0, 0.0-2.8)

Multiple types of complications could occur in a single patient.
*Cells with counts 1-10 were censored in accordance with Healthcare Cost and Utilization Project data use requirements.

data. Thus, we analyzed 26 827 visits among 26 323 children with at least 1 of the 16 conditions that met our power threshold. Appendicitis was the most common condition with an incidence of 1086 cases per million child-years. Demographic characteristics of the cohort are shown in **Table II** (available at www.jpeds.com).

Main Results

Condition-specific complication estimates are shown in **Table III**. Appendicitis, the most frequent condition, was associated with a complication in 24.3% of cases (95% CI 23.7-25.0). Complications were not mutually exclusive and included perforation in 24.1%, abscess drainage in 2.8%, sepsis in 0.9%, and bowel resection in 0.5%. Ovarian torsion had the highest rate of complications, with 59.0% of patients experiencing oophorectomy or salpingectomy. Mortality was highest in stroke (8.4%) and sepsis (5.0%).

Across all conditions, children with complications of their serious condition had the same or longer hospital LOS for encounters beginning within 30 days. There was no difference in median hospital LOS for ovarian torsion and testicular torsion. Differences in median LOS for other conditions ranged from 1 day (ectopic pregnancy) to 18 days (stroke, $P < .05$ for each comparison, **Figure 1** and **Table IV** [**Table IV** available at www.jpeds.com]). Similarly, total charges for all encounters beginning within 30 days were higher among patients with complications across all conditions except diabetic ketoacidosis ($8786, 95% CI −12 269, +29 841). Differences in median charges ranged from $3108 (testicular torsion) to $137 694 (stroke). Among conditions where we did not mandate hospitalization for inclusion, index encounter hospitalization rates were significantly higher among children with complications, with risk differences varying from 20.2% (testicular torsion) to 52.1% (ectopic pregnancy) (**Figure 1**).

Revisit rates are shown in **Figure 2** by condition and time window. Revisit rates were higher among patients with complications of their illness compared with those without. The exceptions to that were among visits for ectopic pregnancy and ovarian torsion, in which patients without complications had higher revisit rates.

Discussion

Across a broad set of serious childhood diseases, complications were common and identifiable using a large, population-based claims database. When complications occurred, they were associated with increased hospitalizations, longer hospitalizations, and higher charges per patient, all lending validity to the definitions of complications.

Our reported complication rates are similar to previous studies. For patients with appendicitis, the rate of appendiceal perforation has been reported to be 25%-29%, similar to our rate of 24%.[4,14,15] Mortality in pediatric sepsis varies, ranging from 5% to 15% depending on whether only children with severe sepsis and shock are included.[53,54] In this study, sepsis mortality among children with and without shock (5%) was at the low end of the previously reported range, given our inclusion of children without severe sepsis or shock. Our results suggest that the rate of oophorectomy or salpingectomy across hospitals of all types is substantially higher than previously reported in pediatric hospitals: 63% vs 35%.[55] This could be due to setting-specific differences in patients or management approaches, and underscores the need for outcomes measurement across settings. The 6.8% bowel resection rate in intussusception in this study is similar to rates reported in the US but is lower than that reported in the United Kingdom (16.8%).[20,22] Similar complication rates between other data sources and our estimates exist for death or rehabilitation in stroke[56]; mechanical ventilation or extracorporeal membrane oxygenation in empyema[36]; seizure, mechanical ventilation, or death in encephalitis; and orchiectomy in testicular torsion.[24] We found lower complication rates than seen in previous studies for patients with bacterial meningitis,[57] myocarditis,[46] and diabetic ketoacidosis.[19] Overall, the validity of our approach for most conditions is supported by our findings that the rates obtained using the methods reported here are consistent with other studies using a range of data sources, methods, and settings.

The complications in this study represent a comparatively worse courses of illness, but may not have been avoidable by actions of healthcare providers and systems. For instance, a late presentation of ectopic pregnancy may mandate surgical management. Appendiceal perforation in appendicitis is more common in younger children and is frequently identified on a child's first presentation.[4] However, regardless of preventability, these complications result in higher rates of surgery, time spent in hospitals, and hospital charges; all outcomes of importance to patients and society. In cases where complications are attributable to late presentations for care, opportunities may exist to promote patients' access to earlier care.

Hospital utilization was generally higher in children with complications of their condition, corroborating the overall more complicated course of these patients. There were some exceptions. For instance, among patients with ovarian

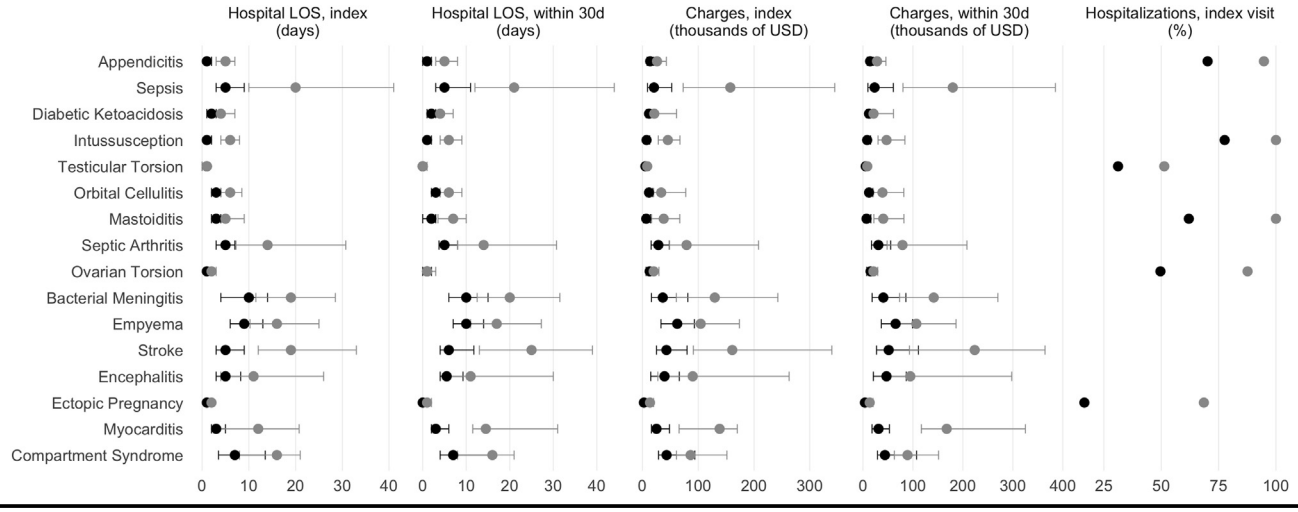

Figure 1. Resource utilization by condition among those with and without complications. Condition-specific median hospital LOS and total hospital charges are shown for both index encounters and for all encounters beginning within 30 days (*black*: patients without complications, *gray*: patients with complications). Ranges represent the 25th-75th percentiles. Hospitalization rates from the index encounter are shown, excluding conditions where hospitalization is required for case identification.

or testicular torsion, inpatient LOS was similar regardless of complication, which is understandable because the postoperative course would not be different. Median charges were higher for all conditions with complications except diabetic ketoacidosis, in which complications were too uncommon to identify a statistical difference in charges. Revisits were similar or higher among children with disease complications, except in ovarian torsion and ectopic pregnancy. We speculate that in ovarian torsion, for uncomplicated cases in which oophorectomy is not performed at the index visit, patients are at greater risk for needing subsequent care related to attempts at salvaging the ovary; in ectopic pregnancy, medical management may be less likely to be successful initially and may result in additional visits to care.[58]

Although timely diagnoses may not avert complications in all cases, comparative evaluation of EDs or health systems would allow for identification of predictors of high complication rates. It would also allow for identification of priority conditions for efforts to reduce complications and thereby increase the health of populations. Measuring the outcomes of many illnesses in large claims datasets is a powerful tool to develop a snapshot of the healthcare of populations. Another advantage of claims data is their utility for measuring outcomes in institutions and systems that do not publish their results, which are disproportionately rural and nonacademic.[6-9] Because virtually all healthcare institutions and systems use common billing methods for insured patients (public and private), these data represent a true cross-section of the population. Thus, although measuring complications in this way does not allow for attribution of complications to disease severity or to the care provided, it provides the means to observe outcomes of patients in hospitals not otherwise easily assessed.

This study overcomes the weaknesses of prior studies that consider data from a single institution or type of institution. There are several other strengths. First, we analyzed a broad range of conditions. Second, we were able to follow children between hospitals to measure their hospital utilization. Third, the definitions of conditions and complications overcomes nongranular diagnosis groupings. For example, although the Diagnosis Grouping System has strengths for grouping conditions in pediatric emergency care, diagnostic categories are insufficiently granular to study single conditions.[59]

These results should be interpreted in the context of several limitations. First, for some conditions, there were very few cases. Second, the process for development of the list of complications did not include input from a wide range of specialties or institutions. This type of input would be critical to the development of robust quality measures of complication rates. However, the complications fell into previously accepted categories and these reviewers were blinded to complication rates. Third, the procedures used to identify complications may not be comprehensive, though the common procedures for each condition were considered for inclusion. Fourth, we included each patient's first apparent visit for a given condition, but we would have missed an earlier diagnosis if it occurred prior to the beginning of our data. Fifth, our methods did not allow for case reviews of individual patients that could have allowed us to assess variability in coding between institutions; however, our complication rates were generally consistent with past reports using clinical data. Sixth, we could not assess long-term complications, though serious complications for the diseases we included would usually occur relatively quickly. Seventh, our data preceded the implementation of *International Classification of Diseases, 10th Revision* (ICD-10) and, thus cannot immediately be applied to ICD-10 data. The codes we report for identifying conditions and complications will require the creation of valid ICD-9 to ICD-10 crosswalks, which have

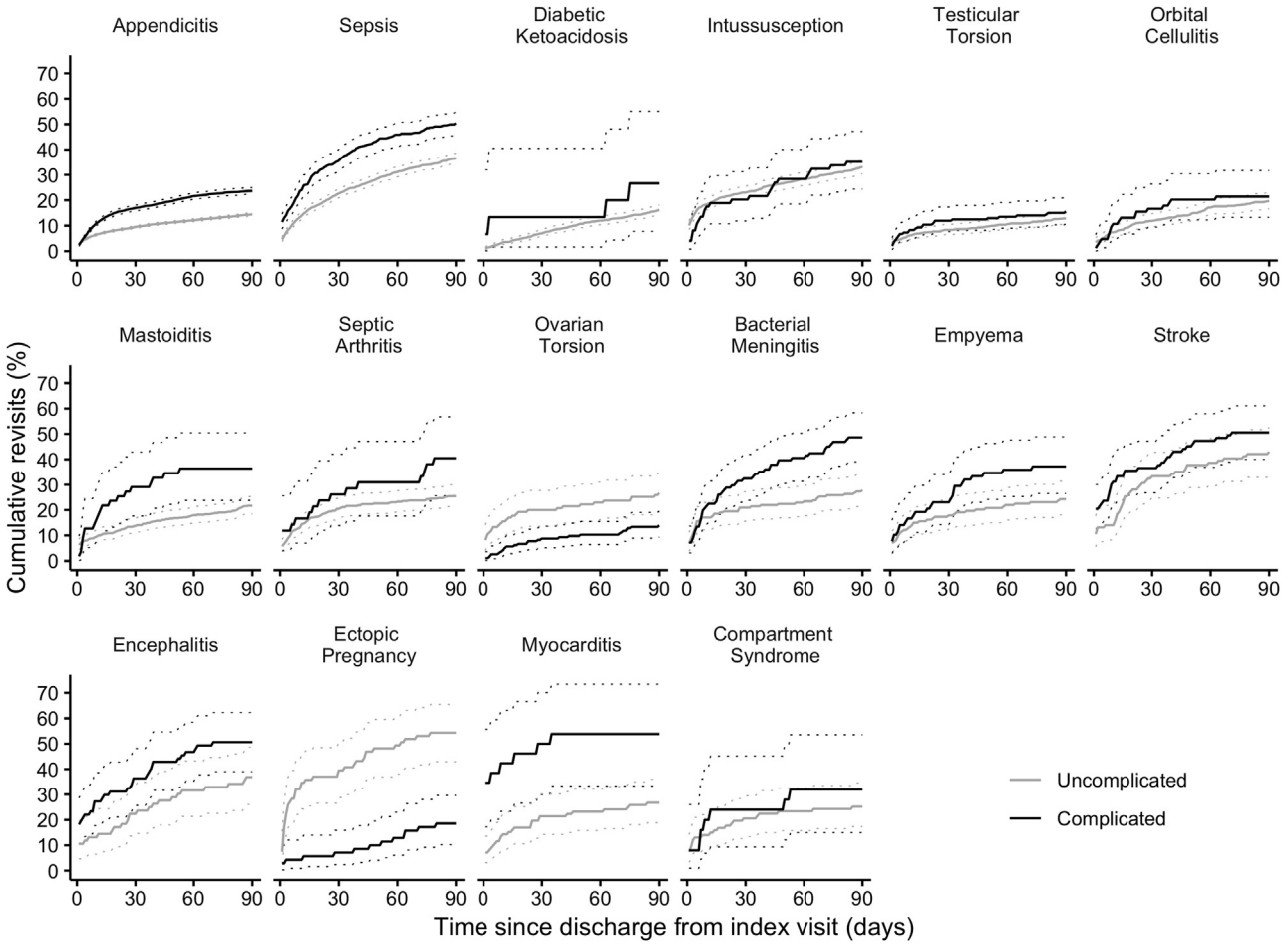

Figure 2. Revisit rates after diagnosis of a serious condition depending on whether the patient had complications. The cumulative proportions of index encounters with a subsequent encounter from 1 to 90 days after ED or hospital discharge are shown. Proportions are given by serious condition, with the denominator of all analyzed encounters, excluding children who died on the index encounter. The dotted lines indicate 95% binomial CIs of the daily cumulative revisit proportion.

successfully been developed for other conditions.[60,61] Finally, validity will be increased by applying these definitions to different data sources and populations to ensure similar performance.

In conclusion, we defined and measured clinically meaningful complications across 16 serious childhood emergency conditions using a large, 2-state, population-based claims database. Complications were common for each condition and were associated with higher resource utilization for most conditions. The use of these definitions can facilitate efforts to identify condition-specific predictors and outcomes of serious pediatric emergency conditions, and can contribute to comparative analysis of complication rates across settings. ■

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Data statement

Data sharing statement available at www.jpeds.com.

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50 Years Ago in *THE JOURNAL OF PEDIATRICS*

Antimicrobial Therapy in Theory and Practice: Clinical Pharmacology

McCracken GH Jr, Eichenwald HF, Nelson JD. J Pediatr 1969;75:742-57

In this Medical Progress report, Drs McCracken, Eichenwald, and Nelson provide an excellent tutorial on 15 classes of antibiotics, many of which had emerged out of industry in the recent explosion of research and development. The authors promised in their introduction to present "… a reasonably factual summary of the pharmacology (in its broadest sense) of antimicrobial agents and then illustrate how knowledge of the basic properties of these drugs can be applied to the rational therapy of a number of infectious clinical syndromes." They go on to say "Furthermore, we must confess that our personal prejudices are reflected to some extent; this is not surprising in a field in which practice is dictated often by prejudice or by an individual's uncontrolled 'clinical experience' (the terms are, of course, synonymous)." The learner is grateful for the revealing of clinical expert opinion.

Reasonable use based on clinical pharmacology was the backbone of this article, as well as their unequaled subsequent contributions as clinical investigators for more than half a century at the University of Texas Southwestern in Dallas. The subspecialty and countless children have been affected profoundly by their early modeling of evidenced-based management. Thank you, from a grateful medical community.

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Table II. Demographic characteristics of the cohort by condition

	All visits for any condition over study period	Appendicitis	Bacterial meningitis	Compartment syndrome	Diabetic ketoacidosis	Ectopic pregnancy	Empyema	Encephalitis	Intussusception	Mastoiditis	Myocarditis	Orbital cellulitis	Ovarian torsion	Sepsis	Septic arthritis	Stroke	Testicular torsion
N	5 728 753	16 794	323	132	1504	151	252	159	1257	644	142	692	329	2808	458	226	956
Incidence (per million child-y)	n/a	1086	20.9	8.5	97.2	9.8	16.3	10.3	81.3	41.6	9.2	44.7	21.3	181.5	29.6	14.6	61.8
Age																	
<1	661 493 (11.5)	11 (0.1)	190 (58.8)	*	*	0 (0.0)	23 (9.1)	*	376 (29.9)	50 (7.8)	22 (15.5)	84 (12.1)	*	963 (34.3)	28 (6.1)	52 (23.0)	14 (1.5)
1-4	1 813 395 (31.7)	679 (4.0)	37 (11.5)	*	165 (11.0)	0 (0.0)	110 (43.7)	29 (18.2)	650 (51.7)	211 (32.8)	16 (11.3)	242 (35.0)	*	643 (22.9)	130 (28.4)	43 (19.0)	47 (4.9)
5-7	829 439 (14.5)	2001 (11.9)	22 (6.8)	11 (8.3)	*	0 (0.0)	45 (17.9)	*	115 (9.1)	137 (21.3)	*	116 (16.8)	14 (4.3)	264 (9.4)	97 (21.2)	18 (8.0)	19 (2.0)
8-11	856 355 (14.9)	4978 (29.6)	30 (9.3)	20 (15.2)	428 (28.5)	0 (0.0)	24 (9.5)	27 (17.0)	44 (3.5)	118 (18.3)	*	114 (16.5)	56 (17.0)	290 (10.3)	99 (21.6)	32 (14.2)	102 (10.7)
12+	1 568 071 (27.4)	9125 (54.3)	44 (13.6)	92 (69.7)	756 (50.3)	151 (100)	50 (19.8)	67 (42.1)	72 (5.7)	128 (19.9)	88 (62.0)	136 (19.7)	244 (74.2)	648 (23.1)	104 (22.7)	81 (35.8)	774 (81.0)
State																	
Maryland	1 247 390 (21.8)	3034 (18.1)	60 (18.6)	28 (21.2)	279 (18.6)	27 (17.9)	44 (17.5)	26 (16.4)	178 (14.2)	121 (18.8)	23 (16.2)	95 (13.7)	54 (16.4)	776 (27.6)	93 (20.3)	50 (22.1)	298 (31.2)
New York	4 481 363 (78.2)	13 760 (81.9)	263 (81.4)	104 (78.8)	1225 (81.4)	124 (82.1)	208 (82.5)	133 (83.6)	1079 (85.8)	523 (81.2)	119 (83.8)	597 (86.3)	275 (83.6)	2032 (72.4)	365 (79.7)	176 (77.9)	658 (68.8)
Sex																	
Female	2 701 419 (47.2)	6546 (39.0)	145 (44.9)	23 (17.4)	800 (53.2)	151 (100)	108 (42.9)	75 (47.2)	451 (35.9)	268 (41.6)	45 (31.7)	268 (38.7)	329 (100)	1411 (50.2)	185 (40.4)	102 (45.1)	0 (0.0)
Male	3 027 203 (52.8)	10 248 (61.0)	178 (55.1)	109 (82.6)	704 (46.8)	0 (0.0)	144 (57.1)	84 (52.8)	806 (64.1)	376 (58.4)	97 (68.3)	424 (61.3)	0 (0.0)	1397 (49.8)	273 (59.6)	124 (54.9)	956 (100)
Race																	
White	1 936 594 (34.4)	8929 (53.7)	142 (44.2)	64 (48.5)	736 (49.4)	31 (20.7)	122 (48.4)	59 (37.3)	518 (41.4)	305 (47.8)	63 (44.7)	255 (37.1)	157 (48.2)	942 (34.0)	214 (47.0)	95 (42.2)	376 (39.9)
Black	1 588 067 (28.2)	1438 (8.6)	68 (21.2)	38 (28.8)	372 (24.9)	56 (37.3)	48 (19.0)	38 (24.1)	273 (21.8)	94 (14.7)	36 (25.5)	199 (29.0)	58 (17.8)	763 (27.5)	92 (20.2)	71 (31.6)	304 (32.2)
Hispanic	1 307 073 (23.2)	3946 (23.7)	53 (16.5)	21 (15.9)	216 (14.5)	43 (28.7)	38 (15.1)	31 (19.6)	263 (21.0)	161 (25.2)	23 (16.3)	115 (16.7)	62 (19.0)	631 (22.8)	67 (14.7)	21 (9.3)	139 (14.7)
Asian/PI	165 228 (2.9)	597 (3.6)	*	*	20 (1.3)	*	21 (8.3)	*	*	*	*	*	*	140 (5.1)	*	*	*
Native American	27 222 (0.5)	70 (0.4)	*	0 (0.0)	11 (0.7)	*	0 (0.0)	*	*	*	*	*	*	19 (0.7)	*	*	*
Other	611 302 (10.8)	1653 (9.9)	39 (12.1)	*	136 (9.1)	19 (12.7)	23 (9.1)	24 (15.2)	130 (10.4)	59 (9.2)	15 (10.6)	87 (12.7)	36 (11.0)	275 (9.9)	68 (14.9)	30 (13.3)	88 (9.3)

(*continued*)

Table II. Continued

	All visits for any condition over study period	Appendicitis	Bacterial meningitis	Compartment syndrome	Diabetic ketoacidosis	Ectopic pregnancy	Empyema	Encephalitis	Intussusception	Mastoiditis	Myocarditis	Orbital cellulitis	Ovarian torsion	Sepsis	Septic arthritis	Stroke	Testicular torsion
Hispanic																	
No	4 088 044 (75.8)	12 030 (75.3)	264 (83.3)	108 (83.7)	1220 (85.0)	99 (69.7)	208 (84.6)	120 (79.5)	961 (78.5)	445 (73.4)	115 (83.3)	543 (82.5)	261 (80.8)	2070 (76.6)	379 (85.0)	201 (90.5)	759 (84.5)
Yes	1 307 073 (24.2)	3946 (24.7)	53 (16.7)	21 (16.3)	216 (15.0)	43 (30.3)	38 (15.4)	31 (20.5)	263 (21.5)	161 (26.6)	23 (16.7)	115 (17.5)	62 (19.2)	631 (23.4)	67 (15.0)	21 (9.5)	139 (15.5)
Child Home																	
Urban	5 266 403 (92.1)	15 401 (92.0)	302 (94.1)	119 (91.5)	1390 (92.6)	*	238 (94.4)	*	1205 (96.2)	583 (90.8)	*	654 (94.6)	314 (95.4)	2657 (94.9)	434 (95.0)	211 (93.8)	912 (95.5)
Rural	451 341 (7.9)	1345 (8.0)	19 (5.9)	11 (8.5)	111 (7.4)	*	14 (5.6)	*	48 (3.8)	59 (9.2)	*	37 (5.4)	15 (4.6)	142 (5.1)	23 (5.0)	14 (6.2)	43 (4.5)
CCC																	
No	4 988 420 (96.0)	16 189 (96.4)	173 (53.6)	120 (90.9)	1375 (91.4)	*	194 (77.0)	73 (45.9)	1166 (92.8)	574 (89.1)	69 (48.6)	629 (90.9)	261 (79.3)	1529 (54.5)	404 (88.2)	75 (33.2)	934 (97.7)
Yes	208 897 (4.0)	605 (3.6)	150 (46.4)	12 (9.1)	129 (8.6)	*	58 (23.0)	86 (54.1)	91 (7.2)	70 (10.9)	73 (51.4)	63 (9.1)	68 (20.7)	1279 (45.5)	54 (11.8)	151 (66.8)	22 (2.3)

PI, Pacific Islander.

*Cells with counts 1-10 were censored in accordance with Healthcare Cost and Utilization Project data use requirements. In cases where a single cell was censored and the cell count could be deduced, the next smallest cell count was also censored. Numbers do not all sum to 100% due to missing data.

Table IV. Hospital utilization by serious condition for the initial encounter and for all encounters within 30 days of the diagnosis visit, among patients who did not die during the index visit

Conditions	Complications	Hospitalization rate, n (%)*	Inpatient days per patient, median (IQR)		Encounters per patient, mean	Charges per patient, median thousands of USD (IQR)	
		Initial encounter	Initial encounter	All encounters	All encounters	Initial encounter	All encounters
Appendicitis	No	8908 (70.2)	1 (1, 2)	1 (0, 2)	1.11	13.8 (8.2, 20.2)	14.3 (8.5, 20.8)
	Yes	3869 (94.8)	5 (3, 7)	5 (3, 8)	1.18	26.0 (15.9, 42.7)	28.1 (16.9, 45.8)
Sepsis	No	2177 (100)	5 (3, 9)	5 (3, 11)	1.21	20.6 (9.1, 52.3)	23.2 (9.8, 60.7)
	Yes	491 (100)	20 (10, 41)	21 (12, 44)	1.20	157.5 (73.0, 344.8)	179.7 (80.1, 385.1)
Diabetic ketoacidosis	No	1486 (100)	2 (1, 3)	2 (1, 3)	1.07	11.8 (6.8, 19.5)	12.1 (6.9, 20.0)
	Yes	15 (100)	4 (2, 7)	4 (2, 7)	1.20	21.1 (13.8, 61.1)	21.1 (13.8, 61.1)
Intussusception	No	913 (77.6)	1 (1, 2)	1 (1, 2)	1.26	7.3 (4.1, 13.1)	8.3 (4.8, 15.3)
	Yes	73 (100)	6 (4, 8)	6 (4, 9)	1.27	45.4 (28.3, 67.2)	47.1 (30.2, 83.9)
Testicular torsion	No	237 (31.1)	1 (0, 1)	0 (0, 0)	1.10	5.2 (3.1, 9.5)	5.4 (3.3, 9.7)
	Yes	99 (51.3)	1 (0, 1)	0 (0, 1)	1.13	8.4 (5.6, 12.3)	8.6 (5.8, 12.7)
Orbital cellulitis	No	606 (100)	3 (2, 4)	3 (2, 4)	1.14	11.8 (6.9, 18.2)	12.2 (7.1, 19.7)
	Yes	83 (100)	6 (4, 8)	6 (4, 9)	1.20	33.6 (19.9, 77.6)	38.9 (20.6, 81.7)
Mastoiditis	No	364 (62.0)	3 (2, 4)	2 (0, 3)	1.16	6.7 (1.9, 14.2)	7.1 (2.1, 15.8)
	Yes	55 (100)	5 (3, 9)	7 (4, 10)	1.33	38.0 (16.3, 66.9)	40.5 (21.8, 81.9)
Septic arthritis	No	416 (100)	5 (3, 7)	5 (4, 8)	1.24	28.4 (15.5, 48)	30.7 (17.0, 55.4)
	Yes	42 (100)	14 (7, 31)	14 (8, 31)	1.05	79.1 (48.3, 208.1)	79.1 (48.3, 208.1)
Ovarian torsion	No	67 (49.6)	1 (1, 2)	1 (0, 2)	1.25	12.8 (6.5, 20.4)	15.1 (7.5, 23.5)
	Yes	170 (87.6)	2 (1, 3)	1 (1, 3)	1.09	20.0 (13.2, 29.5)	20.8 (13.7, 29.6)
Bacterial meningitis	No	205 (100)	10 (4, 14)	10 (6, 15)	1.23	36.4 (16.1, 81.3)	40.7 (18.3, 85.9)
	Yes	111 (100)	19 (12, 28)	20 (12, 32)	1.21	129.6 (60.7, 242.8)	141.6 (73.2, 270.0)
Empyema	No	173 (100)	9 (6, 13)	10 (7, 14)	1.18	62.3 (33.1, 93.1)	65.3 (36.7, 99.2)
	Yes	78 (100)	16 (10, 25)	17 (11, 27)	1.18	104.3 (66.9, 173.7)	106.8 (68.6, 186.3)
Stroke	No	114 (100)	5 (3, 9)	6 (4, 12)	1.31	42.9 (25.1, 80.0)	51.5 (27.1, 111)
	Yes	93 (100)	19 (12, 33)	25 (13, 39)	1.23	161.0 (91.0, 339.5)	223.6 (93.0, 364.4)
Encephalitis	No	76 (100)	5 (3, 8)	6 (4, 9)	1.21	39.5 (14.9, 66)	47.0 (20.7, 86.6)
	Yes	77 (100)	11 (4, 26)	11 (6, 30)	1.26	90.1 (27.5, 262.9)	94.6 (43.8, 297.8)
Ectopic pregnancy	No	13 (16.5)	1 (1, 2)	0 (0, 0)	1.57	2.5 (1.4, 4.5)	3.9 (1.7, 7.4)
	Yes	48 (68.6)	2 (1, 2)	1 (0, 2)	1.07	13.4 (8.4, 19.9)	13.4 (8.4, 20.2)
Myocarditis	No	112 (100)	3 (2, 5)	3 (2, 6)	1.22	25.1 (16, 48.4)	31.1 (18.1, 52.8)
	Yes	26 (100)	12 (2, 21)	14 (12, 31)	1.27	138.3 (65.6, 170.0)	167.6 (116.7, 325.1)
Compartment syndrome	No	107 (100)	7 (4, 14)	7 (4, 16)	1.24	43.2 (28.8, 93.8)	43.9 (29.1, 107.4)
	Yes	25 (100)	16 (8, 21)	16 (8, 21)	1.16	86.3 (61.0, 151.3)	89.1 (62.8, 151.3)

Utilization is stratified by the presence condition-specific complications during the index encounter.
*The case definitions mandated no discharge for sepsis, diabetic ketoacidosis, orbital cellulitis, septic arthritis, bacterial meningitis, empyema, stroke, encephalitis, myocarditis, and compartment syndrome.