Trends in Chest Radiographs for Pneumonia in Emergency Departments

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abstract

BACKGROUND AND OBJECTIVES: National guidelines recommend against routine use of chest radiography (CXR) for community-acquired pneumonia (CAP) diagnosis in the pediatric emergency department (ED). Given that CXR is often used to exclude the diagnosis of CAP, a reduction in CXR use may result in overdiagnosis of CAP. We sought to evaluate trends in CXR use and assess the association between CXR performance and CAP diagnosis among children discharged from pediatric EDs.

METHODS: Children 3 months to 18 years of age discharged from 30 US EDs with (1) CAP or (2) fever or respiratory illness between 2008 and 2018 were included. Temporal trends in CXR use and rates of CAP diagnoses among patients with fever or respiratory illness were assessed. Correlation between hospital-level CXR use and CAP diagnosis rates were evaluated by using Spearman's correlation weighted by hospital volume.

RESULTS: CXR usage decreased from 86.6% to 80.4% ($P < .001$) for patients with CAP and from 30.4% to 18.6% ($P < .001$) for children with fever or respiratory illness over the 10-year study period. CAP diagnosis rates also declined from 7.8% to 5.9% ($P < .001$). Hospital-level CXR use was correlated with pneumonia diagnosis rates (correlation coefficient 0.58; $P < .001$).

CONCLUSIONS: Over the past decade, there has been a decline in CXR use in the ED among children with pneumonia and respiratory illnesses, with a decrease in pneumonia diagnoses over the same time period. Future studies are needed to assess the role of CXR in the evaluation of children with possible pneumonia in the ED setting.

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WHAT'S KNOWN ON THIS SUBJECT: In 2011, the Infectious Diseases Society of America and the Pediatric Infectious Diseases Society published national guidelines recommending against the routine use of chest radiography in the evaluation of community-acquired pneumonia in children presenting to the emergency department.

WHAT THIS STUDY ADDS: Chest radiograph use has decreased over the past decade for children presenting to the emergency department with pneumonia and respiratory illnesses, with an associated decrease in pneumonia diagnosis rates.

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In the United States, community-acquired pneumonia (CAP) accounts for 2.2% of annual visits to pediatric emergency departments (EDs) and represents a leading cause of pediatric hospitalization and readmission.[1–4] Despite the prevalence and significant disease burden associated with lower respiratory tract infection, there remains wide variation in the diagnostic evaluation of children with suspected CAP.[5–7] Reliance on the chest radiograph (CXR) for the diagnosis of CAP varies widely; the authors of 1 study observed a range of CXR usage of 38% to 88% across pediatric EDs.[6] In part, this variation can be explained by recent data revealing that the signs and symptoms of CAP, including auscultatory findings, are not reliably predictive of radiographic CAP.[8]

In an effort to standardize the evaluation and management of CAP, the Infectious Diseases Society of America (IDSA) and the Pediatric Infectious Diseases Society developed a guideline for the diagnosis and treatment of pediatric CAP in 2011.[9] The guideline recommends against the routine use of CXR for diagnostic confirmation of CAP in patients treated in the outpatient setting, reserving its use for children who are hospitalized. In literature in support of this recommendation, it is argued that CXR does not reliably differentiate bacterial from viral pneumonia and therefore does not significantly impact clinical outcomes.[10,11] Subjective evaluation of CXR by providers also makes standardization of CAP diagnosis by imaging difficult.[12–14] Although there is variability of CXR interpretation among radiologists for the assessment of CAP, the inter- and intrarater reliability is higher for findings typically associated with bacterial pneumonia, such as lobar infiltrate and pleural effusion.[13] Finally, although judicious CXR usage in children with common complaints, such as fever and cough, can drive changes in diagnosis and management, it has limited utility when the history and physical examination are consistent with CAP.[15,16]

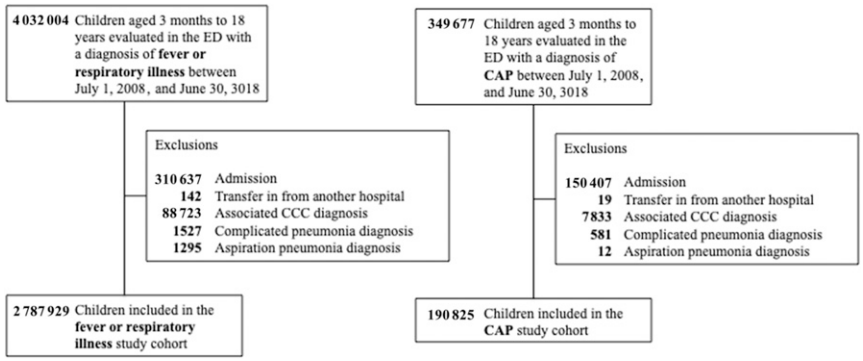

FIGURE 1
Study population. CCC, complex chronic condition.

Reliance on history and physical examination to establish the diagnosis of CAP without performance of a CXR may lead to overdiagnosis and excessive antibiotic prescribing for children with nonpneumonia respiratory illnesses.[8] One recently published study suggests that routine CXR performance in the ED for children with presumed CAP has potential to reduce antibiotic use.[17] Our institution has established a clinical practice guideline recommending CXR usage for children with suspected CAP given recent evidence that CXR is highly effective at excluding CAP (negative predictive value 98.8%), potentially allowing for safe observation of patients without antibiotic therapy.[18]

To measure practice variation in the evaluation of children with suspected CAP in the context of these guidelines, we performed a retrospective cohort study to describe national trends in CXR usage among children evaluated in the EDs of tertiary care pediatric hospitals. We also sought to assess the association between CXR usage

TABLE 1 Patient Characteristics

Patient Characteristics	All ED Visits (N = 17 621 613)	Fever or Respiratory Illness (n = 2 787 929)	CAP (n = 190 825)
Age, y			
<1, *n* (%)	2 205 936 (12)	561 399 (20)	18 671 (10)
1–5, *n* (%)	7 849 908 (45)	1 525 267 (55)	113 768 (60)
6–10, *n* (%)	3 754 311 (21)	459 260 (17)	38 637 (20)
11–18, *n* (%)	3 811 458 (22)	242 003 (9)	19 749 (10)
Median (IQR)	9.1 (4.6–13.6)	2.8 (1.2–6.0)	3.8 (1.8–6.9)
Male sex, *n* (%)	9 331 968 (53)	1 586 701 (57)	101 403 (53)
Race and/or ethnicity, *n* (%)			
Non-hispanic white	5 400 609 (31)	756 071 (27)	57 672 (30)
Non-hispanic African American	4 573 276 (26)	758 029 (27)	42 084 (22)
Hispanic	4 470 252 (25)	647 792 (23)	40 654 (21)
Asian American	316 932 (2)	56 313 (2)	5286 (3)
Other	809 302 (5)	129 704 (5)	8716 (5)
Payer, *n* (%)			
Government	11 149 771 (63)	1 801 746 (65)	114 950 (60)
Private	4 764 747 (27)	673 233 (24)	53 381 (28)
Other	1 262 834 (7)	186 204 (6)	13 463 (7)

IQR, interquartile range.

and CAP diagnosis during the study period. We hypothesized that we would observe a decrease in CXR use and an increase in the overall rate of CAP diagnoses.

METHODS

Study Design and Setting

Data for this study were obtained from the Pediatric Health Information System (PHIS), an administrative database that contains inpatient, ED-level, ambulatory, surgery–level, and observation encounter–level data from 52 not-for-profit, tertiary care pediatric hospitals in the United States. These hospitals are affiliated with the Children's Hospital Association (Lenexa, KS). Data quality and reliability are assured through a joint effort between the Children's Hospital Association and participating hospitals. Portions of the data submission and data quality processes for the PHIS database are managed by Truven Health Analytics (Ann Arbor, MI). For the purposes of external benchmarking, participating hospitals provide discharge and encounter data, including demographics, diagnoses, and procedures. Nearly all of these hospitals also submit resource use data (eg, pharmaceuticals, imaging, and laboratory) into PHIS. Data are de-identified at the time of data submission, and data are subjected to a number of reliability and validity checks before being included in the database. For this study, data from 30 hospitals were included. Twenty-two hospitals were excluded from analysis because of data quality issues or for not having complete ED data for the entirety of the study period.

Study Population

We reviewed encounter-level data from 30 hospitals in PHIS for children aged 3 months to 18 years who were discharged from the ED between July 1, 2008, and June 30, 2018, with a primary diagnosis code for CAP, fever, or respiratory illness. Children with fever or respiratory illness were included in the study to characterize the broader cohort of children for whom CXR may be considered. CAP was defined by a set of previously validated *International Classification of Diseases, Ninth Revision* (ICD-9) diagnosis codes.[19] We selected corresponding *International Classification of Diseases, 10th Revision* (ICD-10) codes to account for the adoption of ICD-10 codes by PHIS on October 1, 2015. Fever and respiratory illness were defined by using codes identified by a previously validated ICD-9–based classification system for health services research in emergency medicine,[20] and these ICD-9 codes were subsequently matched to corresponding ICD-10 codes (Supplemental Table 5). Because we chose 2 distinct previously validated sets of codes to define pneumonia and fever or respiratory illness, there are several overlapping codes that were captured in both cohorts.[19,20] We excluded visits for aspiration pneumonia and complicated pneumonia using a previously defined classification system given the different presentation and diagnostic workup in comparison with CAP.[3,21] Patients with complex chronic conditions were also excluded given their diversity in presentation with respiratory illness and the exclusion of these patients from the guidelines.[22] Patients who were transferred to a study institution from another hospital were also excluded given the inability to ascertain whether a CXR had been obtained before transfer.

TABLE 2 Hospital Characteristics

Hospital Characteristics	All ED Visits (N = 17 621 613)	Fever or Respiratory Illness (n = 2 787 929)	CAP (n = 190 825)
	n (%)	n (%)	n (%)
Geographic region			
Northeast	1 567 197 (9)	233 607 (8)	18 345 (10)
South	7 554 036 (43)	1 251 001 (45)	82 811 (43)
Midwest	5 334 610 (30)	751 101 (27)	53 750 (28)
West	3 165 770 (18)	552 220 (20)	35 919 (19)
Payer mix (% government insurance)			
Q1 (<59)	3 864 714 (22)	623 165 (22)	42 267 (22)
Q2 (59–64)	6 303 237 (36)	937 937 (34)	71 200 (37)
Q3 (65–71)	3 621 783 (21)	546 784 (20)	37 067 (19)
Q4 (>72)	3 831 879 (22)	680 043 (24)	40 291 (21)
No. annual pneumonia ED visits			
Q1 (<298)	2 716 421 (15)	450 438 (15)	20 387 (11)
Q2 (299–512)	3 100 602 (17)	495 611 (18)	30 054 (16)
Q3 (513–797)	4 324 348 (28)	693 418 (25)	52 112 (27)
Q4 (>798)	7 480 242 (39)	1 148 462 (41)	88 272 (46)
No. annual CXRs performed			
Q1 (<2475)	2 263 053 (13)	446 362 (16)	22 077 (12)
Q2 (2476–4085)	3 547 328 (20)	450 369 (16)	31 481 (16)
Q3 (4086–6188)	4 470 035 (25)	693 172 (25)	50 326 (26)
Q4 (>6189)	7 341 197 (42)	1 198 026 (43)	86 941 (46)
Annual ED volume			
Q1 (<35 148)	2 584 021 (15)	410 891 (14)	22 935 (12)
Q2 (35 149–49 202)	2 950 040 (17)	516 696 (19)	28 149 (15)
Q3 (49 203–66 398)	4 236 700 (24)	675 456 (24)	60 808 (32)
Q4 (>66 399)	7 850 852 (45)	1 184 886 (43)	78 933 (41)

Percentage reflects the proportion of total visits in a given region or quartile. Annual numbers for pneumonia ED visits, CXR performances, and ED volume are defined by the average of annual totals over the study period. Q, quartile.

Statistical Analyses

Descriptive patient statistics (frequencies with proportions and medians with interquartile ranges) were used to characterize categorical

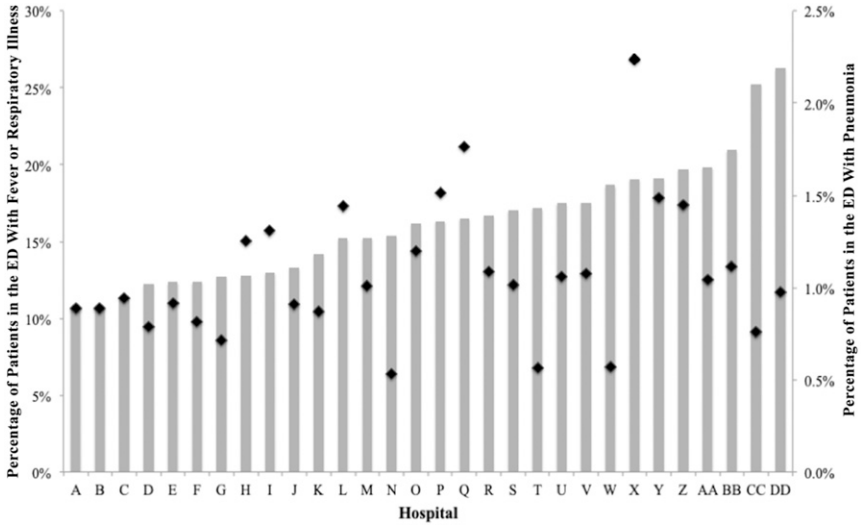

FIGURE 2

Hospital-level rates of CAP and fever or respiratory illness: percentage of patients in the ED with fever or respiratory illness and CAP by hospital. Black diamonds represent patients with pneumonia, and gray bars represents patients with fever or respiratory illness.

and continuous variables. Hospital-level proportions of patients with diagnoses of either CAP or fever or respiratory illness were calculated. Hospitals were characterized by geographic region, payer mix, annual number of CAP and total ED visits, and annual CXR numbers by quartile. To assess hospital-level variation in CAP diagnosis rates, we estimated a logistic regression model with CAP diagnosis as the dependent variable and hospital (modeled as a set of indicator variables) as the independent variable and tested the null hypothesis that the odds of a CAP diagnosis were equal across all hospitals using a Wald test. A significant result would indicate a difference between at least 2 hospitals in the CAP diagnosis outcome. A robust variance estimator was used to accommodate the correlation resulting from the clustering of patients within hospitals. To examine practice variability over time, we estimated a set of logistic regression models with time (modeled monthly) as the independent variable and the following as dependent variables: (1) the proportion of patients with fever or respiratory illness with CXR performed, (2) the proportion of patients with CAP with CXR performed, and (3) the proportion of patients with CAP. To account for seasonal variability in disease incidence, we included Fourier regression terms (ie, sine and cosine terms to capture monthly cyclical patterns in the outcome). Yearly variation in influenza diagnosis rates was not included in the model given the small number of primary influenza patient encounters in comparison with the entire cohort. A significant result would indicate a change in CXR use and CAP diagnoses over time during the study period (July 1, 2008 to June 30, 2018). Interrupted time series analyses were performed to assess for changes in the rates of decline in CXR use and CAP diagnosis before and after IDSA guideline publication. To assess whether changes in CXR usage were associated with changes in revisit rates, we calculated the annual rate of 3-day revisits after an ED visit for patients with fever and respiratory illness, including both ED revisits as well as ED revisits associated with hospitalization. Finally, we correlated hospital-level CXR use with CAP diagnosis rates using Spearman's correlation weighted by hospital volume. All analyses were performed by using the software package Stata SE, version 15.1 (Stata Corp, College Station, TX). All statistical tests were 2-tailed, and α was set at .05. The study was approved by the institutional review board at the study institution.

RESULTS

After review of all eligible patients discharged from the ED with a diagnosis of CAP or fever or respiratory illness and after subsequent removal of patients meeting exclusion criteria, there were 2 787 929 patients included in the fever or respiratory illness cohort and 190 825 patients included in the CAP cohort (Fig 1). The majority of children in both the fever or respiratory illness and CAP cohorts were between 1 and 5 years of age. Children with CAP, and those with fever or respiratory illness, were younger than children seeking care

TABLE 3 Time Series Analyses of CXR Usage and CAP Diagnosis

	Start Rate (July 1, 2008), %	End Rate (June 30, 2018), %	Change, %	OR (95% CI)	*P*
CXR usage					
Overall	9.4	7.4	21.3	0.953 (0.938–0.969)	<.001
Fever or respiratory illness	86.6	80.4	7.2	0.996 (0.995–0.998)	<.001
CAP	30.4	18.4	48.8	0.994 (0.992–0.996)	<.001
CAP diagnosis	7.8	5.9	32.2	0.997 (0.995–0.999)	<.001

for other reasons during the study period (Table 1). There were no material differences in race, ethnicity, or payer between children with fever or respiratory illness or CAP and the overall ED population. In encounters in which the etiology for CAP was specified as part of the diagnosis code, bacterial pneumonia was more common than viral pneumonia (Supplemental Table 6).

ED visits for fever or respiratory illness accounted for 15.8% of all ED visits, and ED visits for CAP accounted for 1.1% of visits. There were no major differences in the hospital characteristics between patients with fever or respiratory illness and those with CAP (Table 2). Children diagnosed with CAP were more likely to be cared for at a hospital in the highest quartile of ED visits for pneumonia. The rate of CAP diagnosis among all ED visits varied across hospitals (range 0.5%–2.2%; Wald test of CAP diagnosis rates across all hospitals: $P < .001$) (Fig 2). Patients with fever or respiratory illness represented 15.8% of visits across all hospitals, with evidence of variation at the hospital level (range 11.1%–26.3%; $P < .001$).

Overall CXR usage decreased over the 10-year study period among all patients presenting to the ED (21.3% decrease; odds ratio [OR] 0.953; confidence interval [CI] 0.938–0.969) (Table 3). CXR use declined from 30.4% to 18.6% (48.8% change; $P < .001$; OR 0.994; CI 0.992–0.996) for children with fever or respiratory illness and from 86.6% to 80.4% (7.2% change; $P < .001$; OR 0.996; CI 0.995–0.998) for children with CAP (Fig 3 A and B). There was a statistically significant decrease in patients diagnosed with CAP from 7.8% to 5.9% during the study period (32.3% change; $P < .001$; OR 0.997; CI 0.995–0.999) (Fig 3C). For both cohorts, using interrupted time series analyses, we observed that the rates of CXR decline did not change

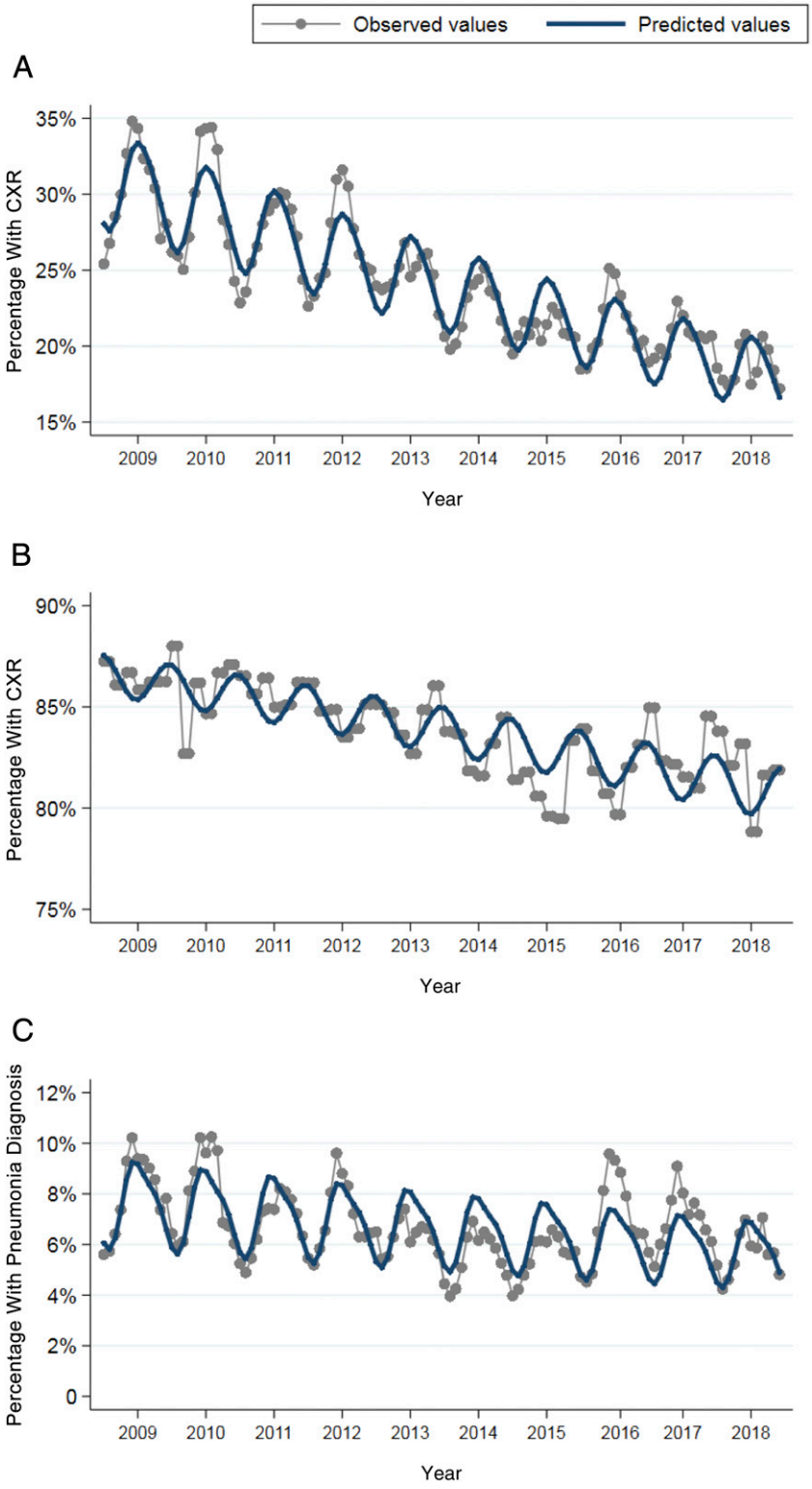

FIGURE 3

Trend analyses for CXR and CAP diagnosis rates. A, Trends in CXR rates for evaluation of fever or respiratory illness: CXR trend over time in patients presenting to the ED for evaluation of fever or respiratory illness (test for linear trend: OR 0.994; CI 0.992–0.996; $P < .001$). B, Trends in CXR rates for evaluation of CAP: CXR trend over time in patients diagnosed in the ED with CAP (test for linear trend: OR 0.996; CI 0.995–0.998; $P < .001$). C, Trends in CAP diagnosis rate: temporal trends in CAP diagnosis rates among patients evaluated in the ED for fever or respiratory illness (test for linear trend: OR 0.997; CI 0.995–0.999; $P < .001$).

significantly after guideline publication. Additionally, rates of decline in CAP diagnoses were also not impacted by the guideline (Supplemental Fig 5). With the decline in CXR usage, we did not observe an increase in 3-day ED revisit rates or ED revisits associated with hospitalization for patents with fever or respiratory illness (Table 4). We observed a direct correlation between hospital-level CXR use and CAP diagnosis rates when weighted by hospital volume (Fig 4). Hospitals that performed more CXRs for patients with fever and respiratory illness observed a higher rate of CAP diagnosis among children with fever or respiratory illness (correlation coefficient 0.58; $P < .001$).

DISCUSSION

In this large cross-sectional study of pediatric patients, we observed a decreasing trend in CXR usage for children with respiratory illnesses overall, and for children with CAP specifically. With these declines, there has been a corresponding decrease in the rate of CAP diagnosis over the study period. Over the course of the study period, we did not observe an increase in revisit rates or subsequent admissions in patients presenting with fever or respiratory illness. We also have identified hospital-level variation in CXR use for patients presenting to the ED with complaints of fever or respiratory illness and have observed a correlation between a hospital's use of CXR and pneumonia diagnosis.

The majority of children diagnosed with CAP had a CXR as part of their initial workup. This finding is consistent with 1 previous study that revealed that >75% of children with a CAP diagnosis receive a CXR in the ED.[5] During the study period, we observed a decline in CXR usage, as measured by trend analysis. This trend was consistent among patients for all ED visits and when stratified by diagnoses specific for CAP and fever or respiratory illness. The steady decline in CXR usage among patients with CAP and among patients presenting with all diagnoses may reflect an increasing emphasis on value-based care and more judicious use of diagnostic imaging over time.[23,24] These findings are also consistent with 1 previous study that documented modest changes in diagnostic testing for patients with a CAP diagnosis, including CXR, after implementation of the 2011 pneumonia guidelines.[7] Given that a decline in CXR use was not associated with increased ED revisit rates or hospitalizations for patients with fever or respiratory illness, we believe that the observed reduction in CXR use did not result in delays in pneumonia diagnosis or return visits for progressively more severe pneumonia.

TABLE 4 Three-Day Revisit Rates to the ED and Associated Admission in Patients With Fever or Respiratory Illness

Year	*N*	Revisit to ED, *n* (%)	ED Revisit With Admission, *n* (%)
2008	111 339	5059 (4.5)	1655 (1.5)
2009	321 913	14 675 (4.6)	4812 (1.5)
2010	293 146	13 199 (4.5)	4303 (1.5)
2011	295 350	13 194 (4.5)	4350 (1.5)
2012	312 574	13 937 (4.5)	4406 (1.4)
2013	282 865	12 032 (4.3)	3931 (1.4)
2014	294 136	12 365 (4.2)	4047 (1.4)
2015	281 985	11 985 (4.3)	3907 (1.4)
2016	235 813	9584 (4.1)	2876 (1.2)
2017	241 856	8536 (3.5)	2434 (1.0)
2018	116 952	2989 (2.6)	834 (0.7)

Our study illustrates significant hospital-level variability in CXR usage for patients with a CAP diagnosis, which is consistent with previous studies revealing hospital-level variation in CAP evaluation.[5,25] When analyzed at the hospital level, increased CXR usage was associated with increased CAP diagnosis rates. This contrasts with 1 previous study in which authors reviewing PHIS data before national guideline implementation observed no association between CXR usage and CAP diagnosis.[6] The observed association between CXR usage and CAP diagnosis may reflect differences in the rates of CAP in baseline patient populations presenting to different EDs. It is possible that the use of CXR may be associated with a reduction in pneumonia diagnoses if CXR is being used to confirm a suspected diagnosis of pneumonia. However, it is also possible that the liberal use of CXR for children with respiratory illnesses may lead to an increase in the overall diagnosis of CAP. Although this study cannot distinguish between these 2 possibilities, we are reassured that the reduction in the use of CXR over time was not associated with an increase in pneumonia diagnoses. Further study is needed to evaluate clinical outcomes in patients discharged from the ED with clinically diagnosed pneumonia (without CXR) to assess for missed CAP diagnoses and to assess provider-level pretest probability for CAP to determine if CXR is being used appropriately. Our findings revealing a decline in both CXR use and CAP diagnoses suggest against the latter, but further study is needed to assess whether physicians are appropriately using CXR for CAP evaluation at the hospital level.

Our study has several important limitations. By extracting data from the PHIS database, we evaluated only freestanding children's hospitals, and as a result, our findings may not be broadly generalizable to other health care settings. Patients presenting to

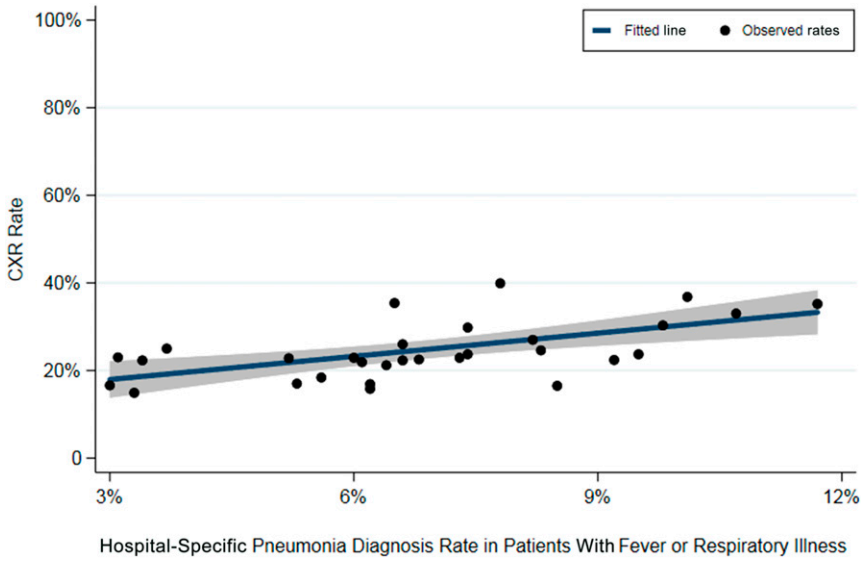

FIGURE 4

Hospital-level rates of CXR usage by CAP diagnosis rate (Spearman's correlation coefficient 0.579, $P < .001$). Analyses are weighted by the number of patients who were discharged per hospital. The solid line represents the fitted values from the linear regression, with shaded area representing the 95% CI.

PHIS hospitals may be sicker than the general population of children in whom CAP may be considered and therefore may introduce a selection bias to this study. The PHIS database does not include information regarding medications prescribed on discharge; thus, we were unable to directly evaluate trends in antibiotic prescribing associated with changes in CXR rates. In classifying diagnoses by ICD-9 and ICD-10 codes, we chose a set of previously validated codes to define CAP and fever or respiratory illness. There may be inherent differences in the coding practices at both the hospital and provider levels among PHIS-participating hospitals that contribute to selection bias. This bias may be minimized by the use of previously described and, in some cases, validated ICD-9 and ICD-10 codes. To capture the patient population in whom a CAP diagnosis may be considered, we intentionally chose a broad definition of fever and respiratory illness. In doing so, we recognize that some of the codes in this classification scheme may not be relevant for a patient undergoing CAP evaluation. Although we excluded patients transferred in from outside hospitals, we were unable to assess in our included patient population testing performed before the ED visit, such as in the outpatient primary care setting.

CONCLUSIONS

Our study reveals hospital-level variation in CXR use and illustrates a decline over the 10-year study period in CXR use for workup of patients presenting to the ED with CAP and respiratory illness. In addition, we found no evidence that decreased CXR use and increased reliance on the history and physical examination for CAP diagnosis were associated with an increase in CAP diagnoses over time. These findings provide reassurance that decreased resource use for CAP diagnosis may not be associated with overdiagnosis of CAP. Future studies are needed to better define the role for CXR in CAP evaluation in the ED and to assess whether variation in CXR usage at the hospital level leads to overdiagnosis of CAP and inappropriate use of antibiotics.

ABBREVIATIONS

CAP: community-acquired pneumonia
CI: confidence interval
CXR: chest radiograph/radiography
ED: emergency department
ICD-9: *International Classification of Diseases, Ninth Revision*
ICD-10: *International Classification of Diseases, 10th Revision*
IDSA: Infectious Diseases Society of America
OR: odds ratio
PHIS: Pediatric Health Information System

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