

Successful Chest Radiograph Reduction by Using Quality Improvement Methodology for Children With Asthma

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OBJECTIVES: Implementation of an asthma clinical practice guideline did not achieve desired chest radiograph (CXR) usage goals. We attempt to use quality improvement methodology to decrease the percentage of CXRs obtained for pediatric patients with acute asthma exacerbations from 29.3% to <20% and to evaluate whether decreases in CXR use are associated with decreased antibiotic use.

METHODS: We included all children ≥ 2 years old at our children's hospital with primary billing codes for asthma from May 2013 to April 2017. A multidisciplinary team tested targeted interventions on the basis of 3 key drivers aimed at reducing CXRs. We used statistical process control charts to study measures. The primary measure was the percentage of patients with an acute asthma exacerbation who were undergoing a CXR. The secondary measure was percentage of patients receiving systemic antibiotics. Balancing measures were all-cause, 3-day return emergency department visits and the percentage of pneumonia and/or asthma codiagnosis encounters.

RESULTS: We included 6680 consecutive patients with 1539 CXRs. Implementation of an asthma clinical practice guideline was associated with decreased CXR use from 29.3% to 23.0%. Targeted interventions were associated with further reduction to 16.0%. For subset analyses, CXR use decreased from 21.3% to 12.5% for treat-and-release patients and from 53.5% to 31.1% for admitted patients. Antibiotic use varied slightly without temporal association with interventions or CXR reduction. There were no adverse changes in balancing measures.

CONCLUSIONS: Quality improvement methodology and targeted interventions are associated with a sustained reduction in CXR use in pediatric patients with acute asthma exacerbations. Reduction of CXRs is not associated with decreased antibiotic use.

Recently, there has been increased recognition of the need for a focused effort to improve the quality of health services, and programs to improve the quality of care for children have greatly expanded.¹ Researchers have used quality improvement (QI) methodology to demonstrate the

improvement of asthma management and outcomes in a variety of settings.^{2,3}

Acute asthma exacerbations are a common cause of emergency department (ED) visits and the most frequent reason for childhood hospitalization in the United States.^{4,5}

abstract



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Drs Watnick and Johnson conceptualized and designed the study, collected data, conducted the analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Drs Arnold, Latuska, and O'Connor conceptualized and designed the study and critically reviewed the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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The National Asthma Education and Prevention Program has created guidelines to help providers manage acute asthma exacerbations.⁶ The authors of these guidelines advise against chest radiographs (CXRs) for routine assessment of patients with acute asthma exacerbations, reserving the use of radiography for patients who are suspected of having an alternative diagnosis, such as pneumothorax, pneumomediastinum, or congestive heart failure.

Many pediatric patients with acute asthma exacerbations still undergo CXRs during their initial evaluation despite these guidelines, often because of concerns of missing a diagnosis concomitant with asthma, such as community-acquired pneumonia. Published rates of CXRs for children presenting with acute asthma range from 27% to 43% and are associated with an increased use of antibiotics,^{7–10} leading to unpleasant side effects for patients and potential increased rates of bacterial antibiotic resistance in the community. A study of >14 000 children presenting to a pediatric ED with asthma revealed that, in reality, <2% of children had concomitant pneumonia on a CXR.¹¹ The authors recommend risk-stratification for CXRs on the basis of specific risk factors instead of routinely obtaining CXRs. Such stratification may help avoid unnecessary antibiotic use on the basis of abnormal but potentially nonpathologic CXR results, the most common of which include hyperinflation and subsegmental atelectasis.¹²

The large variation in the evaluation and management of acute asthma exacerbations despite national guidelines has led to published benchmarks for asthma care. Parikh et al¹³ published benchmark goals for admitted children with acute asthma exacerbations with an achievable benchmark of care of 24.5% for CXR use and 6.6% for antibiotic use. Knapp et al¹⁴ reported

more stringent benchmark goals for the ED treatment of children with acute asthma exacerbations of 17.4% for CXR use and 1.4% for antibiotic use. These benchmarks are important because the use of frequent CXRs may contribute to longer ED length of stays, increased cost, unnecessary radiation exposure, and inappropriate antibiotic use in an era when cost-effective medicine and attention to antibiotic stewardship is paramount.

Hospitals have employed various strategies to meet benchmarks in asthma care. Clinical practice guidelines (CPGs) are systematic and evidence-based guidelines that provide clinical decision support with goals to decrease variability among providers, lower costs, and improve outcomes. Some hospital systems have been successful in reducing CXRs in children with asthma by creating and implementing CPGs.^{15–17} At our institution, the implementation of an asthma CPG did reduce CXR use but did not meet our goal of <20%. The American College of Cardiology and the American Heart Association recently published results from an implementation work group to assess evidence-based strategies for improving the adoption and implementation of CPGs.¹⁸ The report describes the success of educational outreach in improving process of care and clinical outcomes and using multidisciplinary teams and electronic guideline systems to facilitate success of intervention strategies.

Given our inability to reach our CXR goal, we determined to update our hospital's CPG recommendations for CXRs and increase adherence to our asthma CPG by using interventions shown to facilitate improvement in adherence and implementation. Our specific aims were twofold. Our first aim was to use QI methodology to further decrease the percentage of CXRs obtained for pediatric patients with acute asthma exacerbations

from a historical baseline of 29.3% to <20% by December 2016. With this goal, we combined published ED and inpatient asthma care benchmarks. Our second aim was to evaluate whether changes in CXR ordering practices were associated with decreased antibiotic use.

METHODS

Context

Monroe Carell Jr. Children's Hospital at Vanderbilt (MCJCHV) is a 271-bed quaternary care pediatric referral center in Nashville, Tennessee. MCJCHV currently has ~15 000 inpatient admissions and >53 000 ED visits annually. Providers in both inpatient units and the ED use an electronic medical record system and computerized physician order entry. An initial asthma CPG was implemented in May 2014 for a target population of children ≥2 years old with a known diagnosis of asthma and without other chronic comorbidities who presented with acute asthma exacerbations. The CPG included general recommendations against obtaining a CXR in these patients but did not describe the specific CXR indications.

We included all children ≥2 years old presenting to MCJCHV's ED or inpatient units from May 2013 to mid-April 2017. Included children had a primary billing code (*International Classification of Diseases, Ninth Revision* [ICD-9] or *International Classification of Diseases, 10th Revision* [ICD-10]) for asthma (Supplemental Table 2). The data from May 2013 to April 2014 (before the implementation of the initial asthma CPG) served as 1 year of baseline data to compare with postintervention data.

Interventions

We first formed a multidisciplinary team to develop key drivers to identify areas for intervention. The multidisciplinary team included

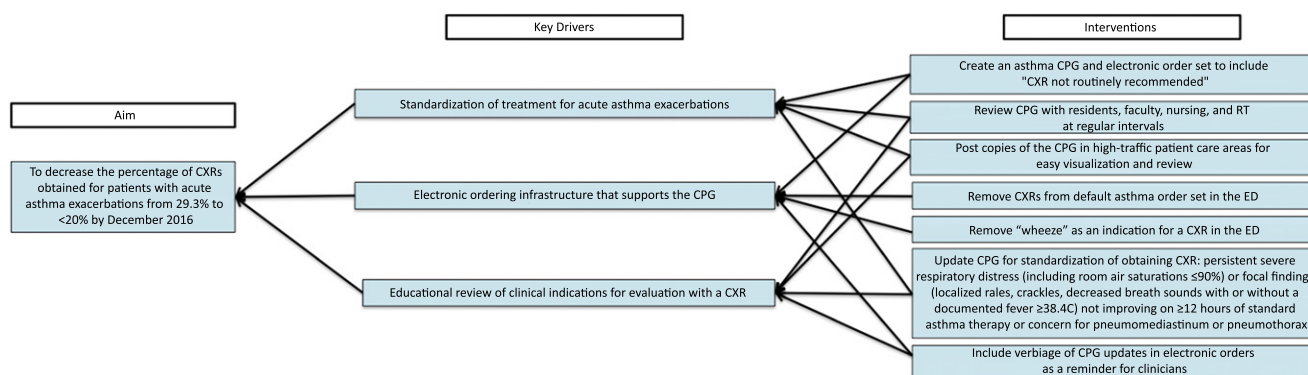


FIGURE 1

Key driver diagram indicating the aim, key drivers, and interventions undertaken. RT, respiratory therapists.

pediatric providers at multiple levels of training and in varied patient care roles to explore potential interventions and implementation strategies from diverse viewpoints. Our leaders included a pediatric hospitalist faculty and pediatric emergency medicine fellow as well as a pediatric emergency medicine faculty, pulmonology fellow, pediatric resident, multiple nurses and nurse practitioners, and 2 respiratory therapists.

We developed 3 key drivers to meet our aims (Fig 1). The first key driver focused on standardization of treatment of acute asthma exacerbations. We updated our asthma CPGs to include specific recommendations for CXR use: "Persistent severe respiratory distress (including room air saturations $\leq 90\%$) or focal findings (localized rales, crackles, decreased breath sounds $\pm$ documented fever $\geq 38.4^\circ\text{C}$) not improving on ≥ 12 hours of standard asthma therapy OR concern for pneumomediastinum or pneumothorax." These specific recommendations were identified to minimize the CXRs obtained prematurely on patients who may not have had sufficient time to respond to bronchodilator and corticosteroid therapy. We posted this updated CPG in high-traffic patient care areas and at physician work places throughout the ED for easy visualization and review.

The second key driver targeted the electronic ordering infrastructure that supported the CPG. CXRs were not included in the inpatient order set that was initially implemented in May 2014. Because the ED order sets were not previously addressed, we elected to remove CXR as an available radio-button order from the electronic asthma ED order set. If a physician did order a CXR, "wheeze" was removed as an indication for obtaining the study (an indication is required for electronic submission). We also included the specific CPG recommendations for obtaining a CXR in the electronic ordering system platform as a real-time, visible reminder for clinicians.

The third key driver prioritized educational review of the clinical indications for obtaining a CXR in our population. We performed in-person education with the emergency medicine and pediatric residents most often placing orders for these patients to improve their understanding of changes and new recommendations. Pediatric emergency medicine and emergency medicine faculty who work in the pediatric ED were educated via e-mail distribution.

Study of the Interventions

Data were obtained via an internally created dashboard that retrieved data for all asthma discharges (Supplemental Table 2) from our

electronic data warehouse. This occurred on a daily basis once billing for the encounter was complete, which was usually a 3- to 4-day delay from the end of the encounter. Given that defining the relationship between attempted interventions and observed changes in processes was essential to increasing the degree of belief that interventions led to results, we used an analytical approach for our study instead of an enumerative approach.¹⁹ Statistical process control charts were used to study all measures, allowing the team to visually draw inferences from temporal relationships of interventions and results.

Measures

Our primary measure was the percentage of children with an acute asthma exacerbation who received a CXR during their visit, which included ED treat-and-release visits and inpatient hospitalizations. Our secondary measure was the percentage of children with an acute asthma exacerbation who received systemic antibiotics during their visit. Our first balancing measure looked at all-cause, 3-day return ED visits to assess whether there were unintended consequences (ie, increased return visits) in the setting of decreased CXR use. With our second balancing measure, we looked at the proportion of encounters with a primary pneumonia diagnosis

TABLE 1 Definition of Measures

Measurement Type	Measure	Definition
Outcome	Percentage of encounters with a CXR	Percentage of all acute asthma exacerbation encounters (both ED treat-and-release and hospitalizations) in which patients underwent a CXR at any time during their visit
	Percentage of encounters treated with systemic antibiotics	Percentage of all acute asthma exacerbation encounters (both ED treat-and-release and hospitalizations) in which patients received any systemic antibiotics (β -lactams, cephalosporins, and/or macrolides) during their visit
Balancing	3-d ED return visits	Percentage of all ED treat-and-release acute asthma exacerbation encounters in which patients returned to the ED within 3 midnights for any complaint
	Percentage of primary pneumonia with secondary asthma codiagnosis	Monthly no. patients who were coded as having a primary diagnosis of pneumonia and secondary diagnosis of asthma (both ED and hospitalized) divided by the no. those same patients plus the total monthly asthma cohort

(Supplemental Table 2) and a secondary asthma diagnosis to determine if our results could be explained by shifts in coding away from asthma as a primary diagnosis (Table 1).

Analysis

We followed our interventions by using annotated statistical process control charts which were created by using QI Charts software (Performance Improvement Products, Austin, TX). Because of asthma exacerbation seasonality and the importance of analyzing data frequently, patients were organized into groups of 40 consecutive discharges, and the percentage of children receiving a CXR was plotted on a p-chart. A second annotated p-chart was used to follow the percentage of children receiving systemic antibiotics. Special cause variation, or nonrandom change within the system, was defined as a single data point outside of the control limits or 8 consecutive points greater than or less than the mean.¹⁹ We performed subanalyses of ED treat-and-release and hospitalization encounters. Our subanalysis ended in March 2017 and did not include the final 16 patients in the 40-patient subgroup seen in April 2017 from our primary analysis.

Ethical Considerations

Our study was approved by our institutional review board as

nonresearch QI before beginning our analysis.

RESULTS

Primary Measure

Data were collected for 48 months, including 6680 consecutive patient visits meeting ICD-9 and/or ICD-10 criteria that received 1539 CXRs. Hospital-wide implementation of an initial asthma CPG was associated with a reduction in CXR use from 29.3% to 23.0%. Targeted QI methodology stemming from our key drivers was associated with further reduction and 14-month sustainment in CXR use to 16.0% (Fig 2). A review of the CXRs in the single data point outside of our control limits after our focused interventions (August 2016) did not reveal any specific pattern to suggest a cause for increased CXRs in this cohort of patients, although it is possible that at the beginning of a new academic year there were less experienced trainees initiating imaging orders before discussion with their supervising physicians.

Our subanalysis revealed 5183 (77.8%) ED treat-and-release visits and 1481 (22.2%) children seen in the ED and admitted for ongoing asthma treatment. For the treat-and-release population, CXR use was reduced from 21.3% to 12.5% after 1 of our targeted interventions (Fig 3) and has been sustained for 21 months. For the admitted population, CXR use was reduced from 53.5%

to 31.1% after additional targeted interventions (Fig 4) and has been sustained for 14 months.

Secondary Measure

The percentage of children with acute asthma exacerbations receiving systemic antibiotics decreased from 6.9% to 4.4% but was not associated with the timing of our CXR reductions (Fig 5). During our final 4 months of data collection, we saw a slight increase in antibiotic use up to 7.8%. When analyzing data on the basis of visit type, the percentage of ED treat-and-release patients receiving antibiotics remained stable at 2.3% without change at any point in the study period. The percentage of admitted patients receiving antibiotics decreased from 20.7% to 12.7% with publication of the initial asthma CPG (data not shown).

Balancing Measures

There was a slight favorable decrease in all-cause, 3-day return ED visits from 4.3% to 3.7% beginning in March 2015, but this was not associated with specific intervention related to CXR reduction (data not shown). The percentage of encounters with primary pneumonia and secondary asthma codiagnoses did not reveal special cause variation that would result in a shift of the mean after the demonstrated CXR reduction in February 2016 (Fig 6).

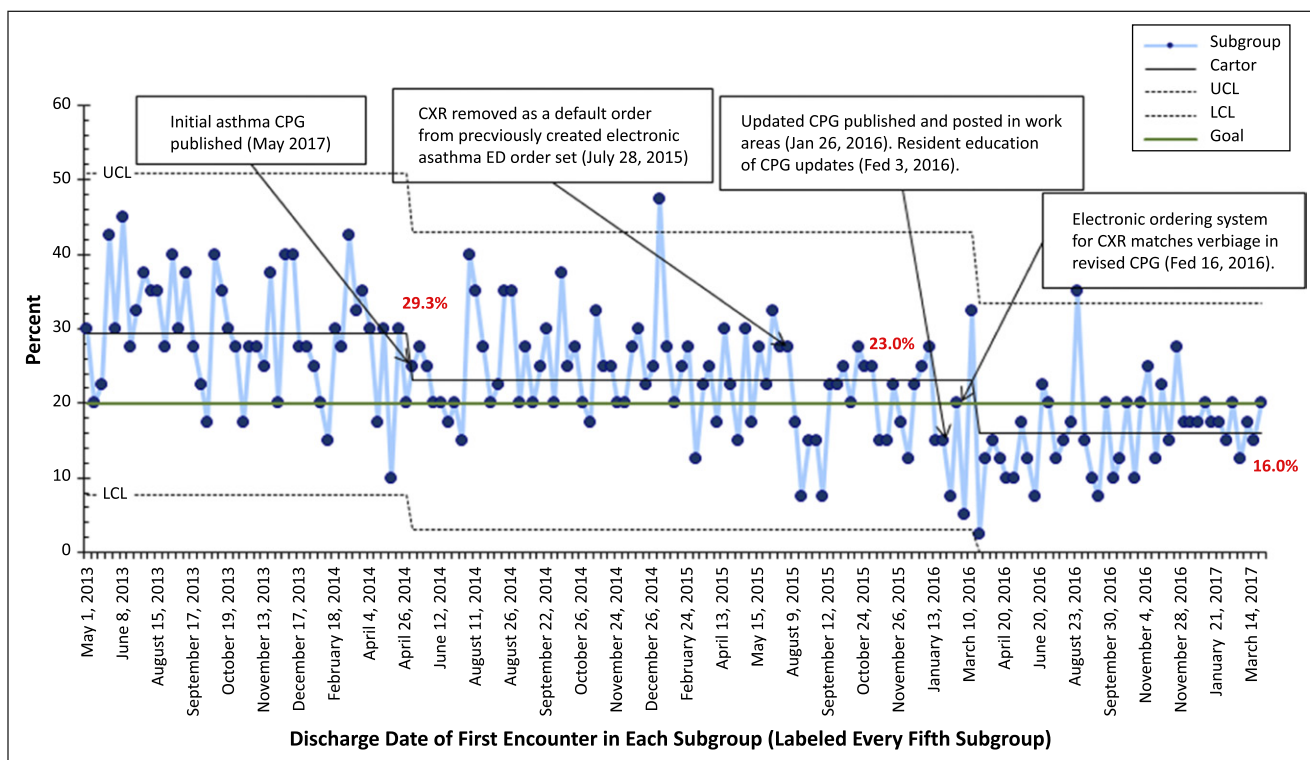


FIGURE 2

Percentage of all primary diagnosis asthma encounters in consecutive cohorts of 40 discharges in which patients underwent a CXR during their visit. LCL, lower control limit; UCL, upper control limit.

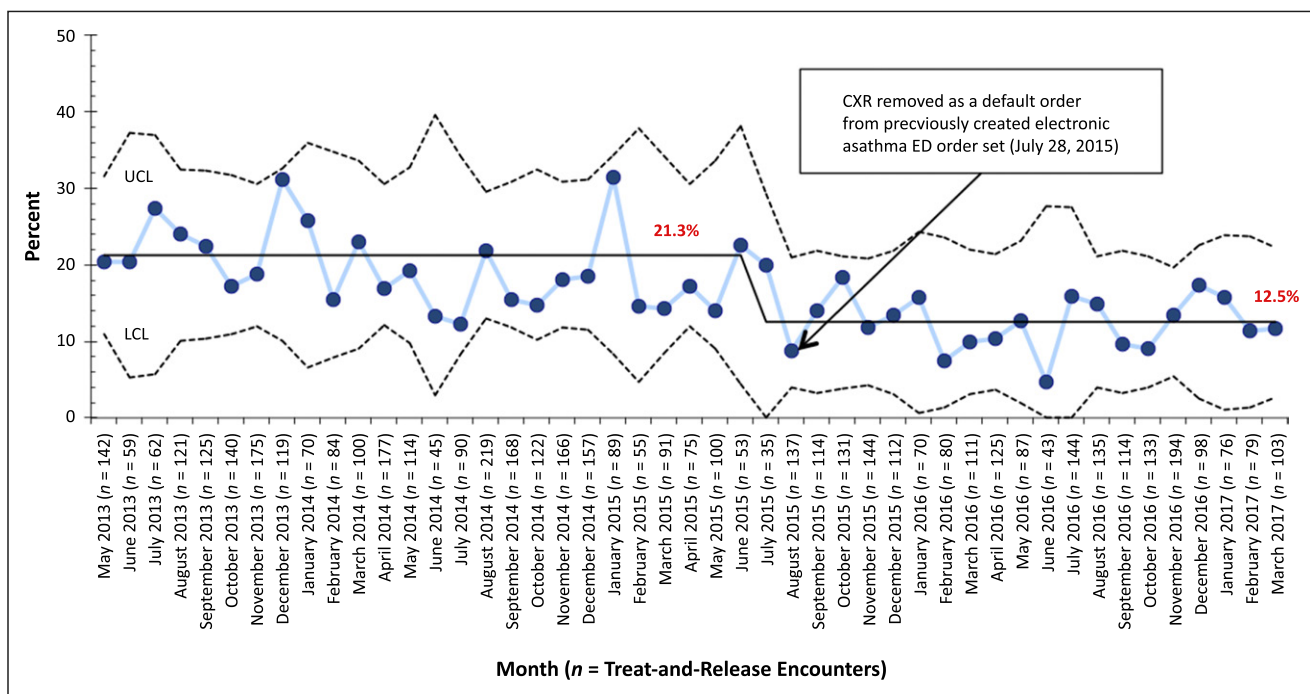


FIGURE 3

Percentage of all primary diagnosis asthma encounters each month in which patients received a CXR and were treated and released after receiving care in the ED. LCL, lower control limit; UCL, upper control limit.

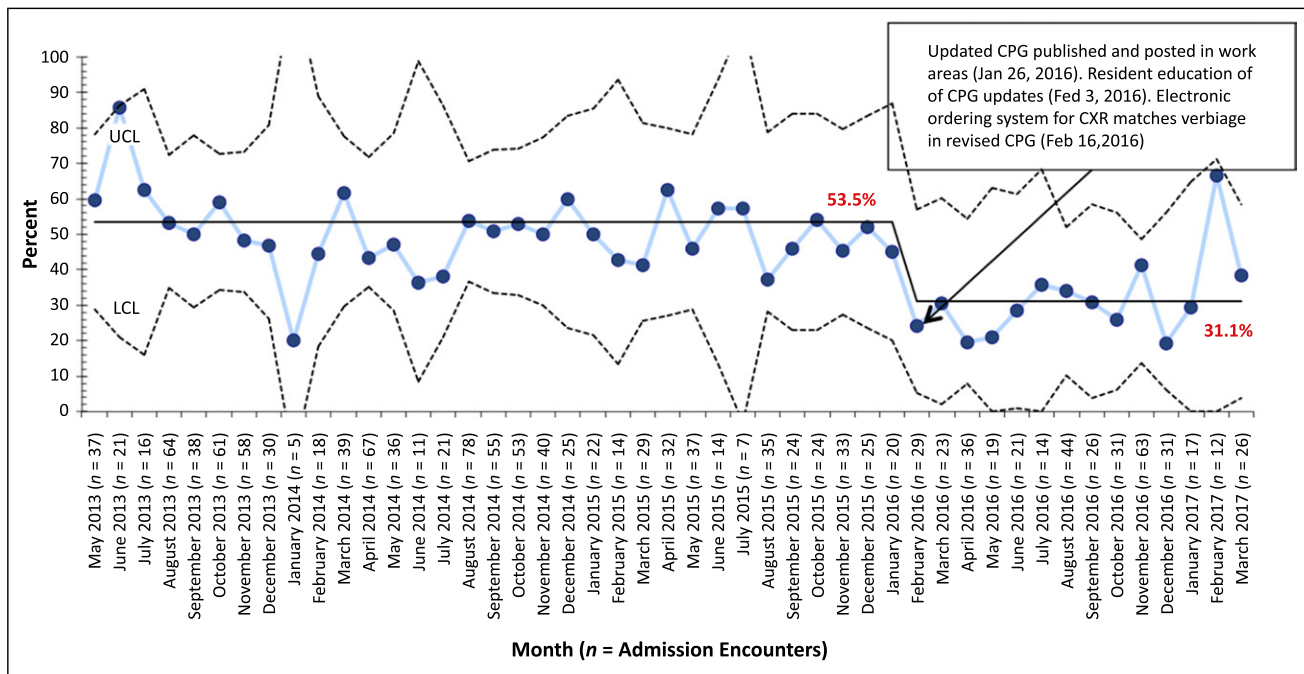


FIGURE 4
Percentage of all primary diagnosis asthma encounters each month in which patients received a CXR during an encounter that included hospitalization. LCL, lower control limit; UCL, upper control limit.

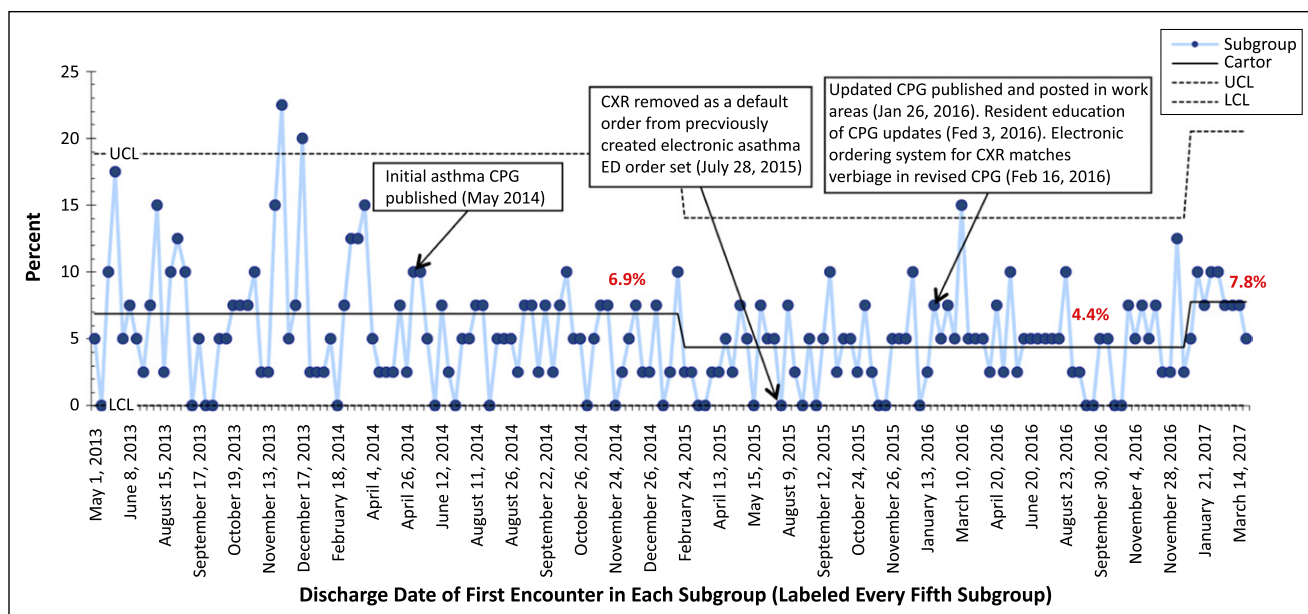


FIGURE 5
Percentage of all primary diagnosis asthma encounters in consecutive cohorts of 40 discharges in which patients received systemic antibiotics during their visit. LCL, lower control limit; UCL, upper control limit.

DISCUSSION

Targeted QI methodology is associated with a sustained reduction in overall CXR use from 29.3% to 16.0% in pediatric patients

with acute asthma exacerbations. Our subanalyses reveal that our interventions had differing impacts on different units, with interventions to the electronic ED order set having more impact on CXRs obtained for ED

treat-and-release patients, whereas updates to the verbiage, distribution, and education surrounding the CPG had more impact on CXRs obtained in admitted patients. Contrary to previous reports in the literature,^{8–10}

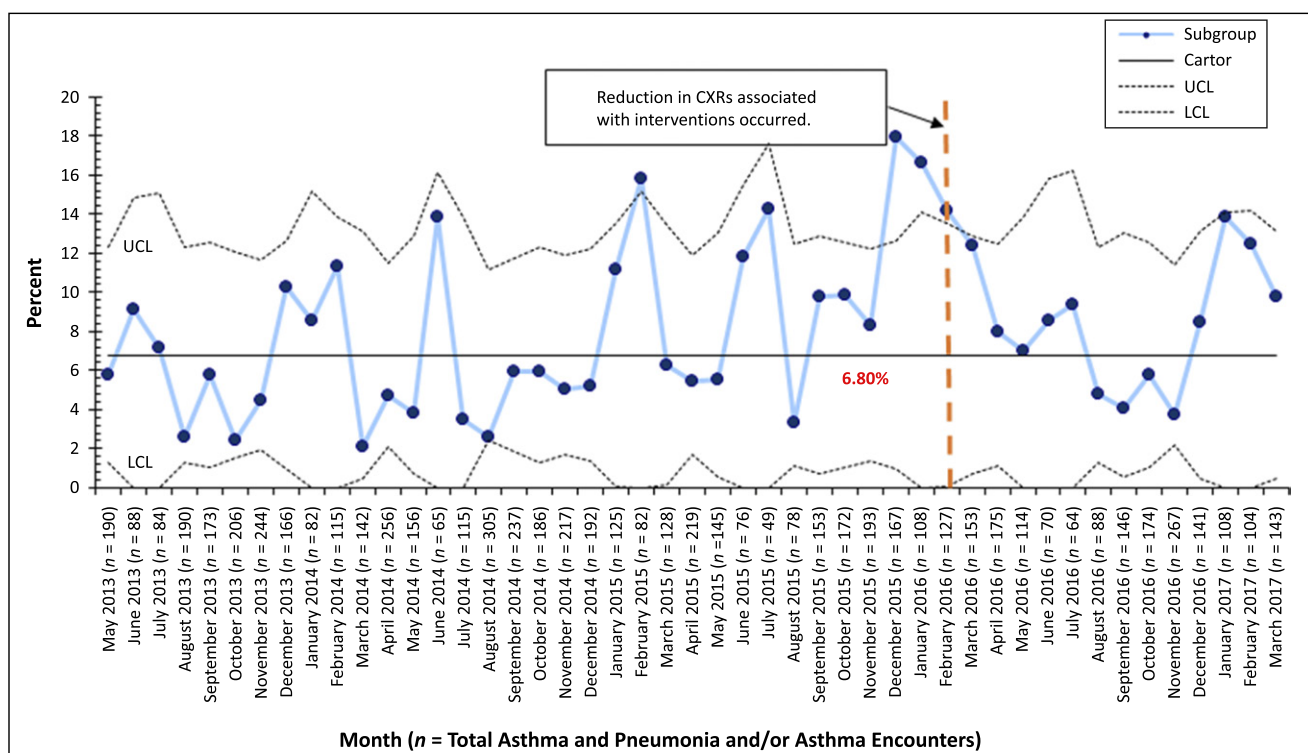


FIGURE 6

Percentage of encounters with a primary pneumonia and secondary asthma diagnosis with a denominator of primary asthma diagnosis (main cohort) plus primary pneumonia and/or secondary asthma codiagnosis encounters. LCL, lower control limit; UCL, upper control limit.

CXR reduction was not associated with decreased antibiotic use in our cohort.

To our knowledge, our robust data set of >6000 patients over 4 years is currently the largest published series revealing sustained reduction in CXR use for children with acute asthma exacerbations. After an initial slight reduction in CXR ordering after the implementation of an asthma CPG, we were able to accomplish further and sustained reduction by using targeted QI methodology despite frequent changes in personnel. Our quaternary care teaching hospital includes rotating trainees from the departments of pediatrics, emergency medicine, and a neighboring hospital's family medicine program. Our decrease in CXR ordering practices was maintained despite monthly changes in these ordering providers, suggesting that use of a CPG, changes to the electronic ordering infrastructure, and

education are associated with sustained improvements despite frequent changes in staff. Our interventions were associated with the lowest overall rates of CXR use in children with acute asthma exacerbations compared with the current literature.^{15–17} Our balancing measure indicates that these reductions in CXRs cannot be explained by a shift in coding practices identifying higher proportions of children with a primary pneumonia and/or secondary asthma codiagnosis. Subanalysis of our primary outcome into ED treat-and-release patients versus admitted patients reveals that the decrease in CXR use in both populations occurred immediately after targeted QI interventions, suggesting an association between interventions and outcomes. After removing CXR as a selectable radio-button from the electronic ED order set, there was a significant decrease in CXRs to 12.5% for

treat-and-release patients, well below the published benchmark goal of 17.4% described by Knapp et al.¹⁴ Admitted patients also experienced a decrease in CXR use after additional interventions, including updating the existing CPG, modifying the electronic ordering system, and performing in-person educational sessions to review CPGs with residents. Although our outcomes for admitted patients do not meet the published benchmark goal for CXRs of <24.5% as described by Parikh et al,¹³ we did succeed in reducing CXR use at our institution by 42%. Presumably, these patients who required hospital admission were more ill on their initial ED presentation, and therefore more likely to have a CXR performed. This population is the target for our most immediate next steps to bring our CXR percentage within published benchmark goals for admitted patients. With our CPG, we suggest providing ≥12 hours of standard asthma therapy before performing

imaging, so an educational review of this recommendation appears to be a logical next step for improvement and would be supported by the Society of Hospital Medicine's Pediatric Hospital Medicine Choosing Wisely initiative, which recommends against CXRs in children with uncomplicated asthma.²⁰

Reducing CXRs during acute asthma exacerbations can have important implications for both the patient (avoidance of unnecessary radiation exposure) as well as for the hospital system (lowering cost and improving efficiency). Our data reveal that decreasing the use of CXRs is not associated with increased morbidity to the patient because there was no increase in all-cause, 3-day ED return visits despite changes in imaging frequency, likely representing low numbers of missed diagnoses related to lack of imaging. This also ensures no additional cost to the hospital system related to repeat visits for initially missed diagnoses.

A review of our secondary measure revealed that systemic antibiotic administration remained low before and after interventions. The minor changes in antibiotic use did not correspond to changes in CXR ordering or to our documented interventions. The decrease in antibiotic use for admitted patients occurred with the publication of the initial asthma CPG, but no additional decreases occurred with targeted QI interventions. Although decreased CXR use is not associated with decreased antibiotic use in this study, it is encouraging that our overall rates of antibiotic use remain low, despite not meeting published benchmark goals.

Our study has limitations. Use of billing codes for patient identification is error prone and subject to inaccuracies.^{21,22} However, it allowed us to research and study large pools of data in near real time that would not have been feasible if performed manually. To provide rapid data

for analysis, the dashboard logic returned all patients with a primary diagnosis of asthma. Therefore, our study population may include patients who have a primary asthma diagnosis but also have complex medical problems such as cystic fibrosis or chronic respiratory failure with tracheostomy dependence and are more likely to have a CXR performed when ill. We were also unable to exclude children with no known diagnosis of asthma (ie, the child with "first time wheeze"), although by including children ≥ 2 years old we tried to limit this number. Finally, we did not have information on the indication for antibiotic administration. It is possible that antibiotics were used for a reason other than possible pneumonia seen on a CXR, such as acute otitis media. Conversely, children treated with antibiotics for possible pneumonia seen on a CXR may not have been coded as asthma and therefore missed in our data set, although our balancing measure reveals there was no change in this coding after our demonstrated CXR reduction.

Our study may be generalizable if performed in other similar institutions. Our hospital is a quaternary care children's hospital with pediatric specific personnel including physicians, nurses, and respiratory therapists. As such, there was substantial buy in to limit radiation exposure in our patients. Our interventions and study approach may not be generalizable to settings in which pediatric patients comprise only a small proportion of patient volume.

Overall, an asthma CPG resulted in modest reductions in CXR use, but QI methodology and targeted interventions were associated with a sustained and safe reduction in CXR use for pediatric patients with acute asthma exacerbations. Our high-yield interventions were at essentially no monetary cost and

low time cost to team members to plan, test, and analyze changes and could theoretically be efficiently and easily incorporated at other institutions. With our interventions, we set a framework for improvement that could be expanded for other purposes or disease processes as well.

ABBREVIATIONS

CPG: clinical practice guideline
 CXR: chest radiograph
 ED: emergency department
 ICD-9: *International Classification of Diseases, Ninth Revision*
 ICD-10: *International Classification of Diseases, Tenth Revision*
 MCJCHV: Monroe Carell Jr. Children's Hospital at Vanderbilt
 QI: quality improvement

REFERENCES

1. Ferris TG, Dougherty D, Blumenthal D, Perrin JM. A report card on quality improvement for children's health care. *Pediatrics*. 2001;107(1):143–155
2. Cockerham JR, Lowe GR, Willis R, Stecks RM, Berlinski A. Quality improvement project to improve timeliness between bronchodilator treatments from emergency department to medical wards. *Respir Care*. 2016;61(12):1573–1579
3. Bravata DM, Gienger AL, Holty JE, et al. Quality improvement strategies for children with asthma: a systematic review. *Arch Pediatr Adolesc Med*. 2009;163(6):572–581
4. Akinbami LJ, Moorman JE, Garbe PL, Sondik EJ. Status of childhood asthma in the United States, 1980–2007. *Pediatrics*. 2009;123(suppl 3):S131–S145
5. Merrill CT, Owens PL. Reasons for Being Admitted to the Hospital through the Emergency Department for Children and Adolescents, 2004. HCUP Statistical Brief #33. Agency for Healthcare Research and Quality, Rockville, MD.

2007. Available at: www.hcup-us.ahrq.gov/reports/statbriefs/sb33.pdf. Accessed June 1, 2017
6. National Asthma Education and Prevention Program; National Heart, Lung, and Blood Institute. Expert panel report 3: guidelines for the diagnosis and management of asthma. Available at: <http://www.nhlbi.nih.gov/guidelines/asthma/asthgdln.pdf>. Accessed June 1, 2017
7. Stanley RM, Teach SJ, Mann NC, et al; Pediatric Emergency Care Applied Research Network. Variation in ancillary testing among pediatric asthma patients seen in emergency departments. *Acad Emerg Med*. 2007;14(6):532–538
8. Davies G, Paton JY, Beaton SJ, Young D, Lenney W. Children admitted with acute wheeze/asthma during November 1998–2005: a national UK audit. *Arch Dis Child*. 2008;93(11):952–958
9. Narayanan S, Magruder T, Walley SC, Powers T, Wall TC. Relevance of chest radiography in pediatric inpatients with asthma. *J Asthma*. 2014;51(7):751–755
10. Chamberlain JM, Teach SJ, Hayes KL, Badolato G, Goyal MK. Practice pattern variation in the care of children with acute asthma. *Acad Emerg Med*. 2016;23(2):166–170
11. Florin TA, Carron H, Huang G, Shah SS, Ruddy R, Ambroggio L. Pneumonia in children presenting to the emergency department with an asthma exacerbation. *JAMA Pediatr*. 2016;170(8):803–805
12. Brooks LJ, Cloutier MM, Afshani E. Significance of roentgenographic abnormalities in children hospitalized for asthma. *Chest*. 1982;82(3):315–318
13. Parikh K, Hall M, Mittal V, et al. Establishing benchmarks for the hospitalized care of children with asthma, bronchiolitis, and pneumonia. *Pediatrics*. 2014;134(3):555–562
14. Knapp JF, Hall M, Sharma V. Benchmarks for the emergency department care of children with asthma, bronchiolitis, and croup. *Pediatr Emerg Care*. 2010;26(5):364–369
15. Gildenhuys J, Lee M, Isbister GK. Does implementation of a paediatric asthma clinical practice guideline worksheet change clinical practice? *Int J Emerg Med*. 2009;2(1):33–39
16. Buckmaster A, Boon R. Reduce the rads: a quality assurance project on reducing unnecessary chest X-rays in children with asthma. *J Paediatr Child Health*. 2005;41(3):107–111
17. Bekmezian A, Fee C, Weber E. Clinical pathway improves pediatrics asthma management in the emergency department and reduces admissions. *J Asthma*. 2015;52(8):806–814
18. Chan WV, Pearson TA, Bennett GC, et al. ACC/AHA special report: clinical practice guideline implementation strategies: a summary of systematic reviews by the NHLBI Implementation Science Work Group: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol*. 2017;69(8):1076–1092
19. Provost LP, Murray S. *The Health Care Data Guide: Learning From Data for Improvement*. San Francisco, CA: John Wiley & Sons, Inc; 2011
20. Society of Hospital Medicine: Pediatric Hospital Medicine. Don't order chest radiographs in children with uncomplicated asthma or bronchiolitis. Available at: www.choosingwisely.org/clinician-lists/society-hospital-medicine-pediatric-chest-radiographs-for-uncomplicated-asthma-bronchiolitis/. Accessed January 5, 2018
21. O'Malley KJ, Cook KF, Price MD, Wildes KR, Hurdle JF, Ashton CM. Measuring diagnoses: ICD code accuracy. *Health Serv Res*. 2005;40(5, pt 2):1620–1639
22. Surján G. Questions on validity of International Classification of Diseases-coded diagnoses. *Int J Med Inform*. 1999;54(2):77–95

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