

DIAGNOSTICS

Relevance of chest radiography in pediatric inpatients with asthmaSridaran Narayanan, MD¹, Terri Magruder, MD², Susan Chu Walley, MD¹, Tony Powers, RRT³, and
Terry Craft Wall, MD, MPH⁴¹Pediatric Hospital Medicine and ²Pediatric Pulmonology and Sleep Medicine, UAB, Birmingham, AL, USA, ³Children's of Alabama, Respiratory Case Services, Birmingham, AL, USA, and ⁴Department of Pediatrics, UAB, Birmingham, AL, USA**Abstract**

Introduction: The goals of this study are to identify factors associated with ordering of chest radiographs (CXR's) in children hospitalized with acute asthma exacerbations and determine the overall clinical impact of these CXR's. **Methods:** A retrospective study was performed with children ≥ 2 years of age admitted from our emergency department (ED) between 6/1/2011 and 5/31/2012 with a primary diagnosis of acute asthma exacerbation or status asthmaticus. Patients were excluded if they had been on antibiotics prior to the emergency visit, received continuous albuterol or intravenous magnesium during the hospitalization, or had another chronic disease affecting lung function. **Results:** 180 of the 405 children in the study (44%) had CXR's ordered, of which 18 (10%) had imaging that altered the patient's treatment plan. There were six cases of radiologist-diagnosed pneumonia, nine cases of atelectasis treated with antibiotics and three cases of pneumothorax. Factors associated with CXR ordering were: fever at home or in the ED (OR 4.5, 95% CI 2.8–7.4), triage oxygen saturation less than or equal to 92% (OR 1.8, 95% CI 1.2–2.7) and age 4 years or less (OR 2.3, 95% CI 1.4–3.7). Patients with treatment-altering CXR's were more likely to have oxygen saturations less than or equal to 92% (OR 4.2, 95% CI 1.4–13.0; $p = 0.006$) or fever in the ED (OR 3.8, 95% CI 1.0–13.6; $p < 0.05$). No patients with triage oxygen saturation above 96% had a treatment-altering CXR. **Conclusions:** The majority of CXR's ordered in pediatric inpatients with asthma exacerbation do not provide clinically relevant information.

Keywords

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History

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Introduction

Published guidelines for the inpatient care of children with acute asthma exacerbation recommend “[reserving] chest X-rays for children with severe disease or clinical clues suggesting other conditions” such as pneumonia, pneumomediastinum or pneumothorax [1,2]. However, chest radiographs (CXR's) are ordered in 33 to 43% of children seen in emergency departments (ED's) for asthma [3], with wide inter-facility variation in rates of ordering and no consistent criteria for ordering rationale [3,4]. Presence of fever has been associated with increased rates of CXR ordering [3–5], but a 2007 ED study showed that even 32% of afebrile patients with normal oxygen saturations had radiographs ordered [4].

In children who wheeze, rates of abnormal CXRs range from 5% to 7% [6,7], with lower rates when accounting for readings of segmental atelectasis [8] and those with a known history of asthma [6]. Abnormal CXR findings in wheezing children have been associated with high fever $>39^{\circ}\text{C}$, triage hypoxia $<92\%$, abdominal pain and localized rales on exam [7–9]. The abnormalities seen most often on CXRs are hyperinflation and segmental or subsegmental atelectasis,

with pneumonia being much less common [6]. Pneumomediastinum is seen in less than 1% of asthmatics [6,8] and is associated with triage hypoxia, with generally uncomplicated recovery [10].

The objectives of this study are to identify factors associated with (1) ordering of chest radiographs in children hospitalized with acute asthma exacerbations, and (2) having a radiograph result that alters treatment plan.

Methods

This is a retrospective study of patients between 2 and 19 years of age, admitted from the pediatric ED at Children's of Alabama (an urban tertiary care children's hospital) between 1 June 2011 and 31 May 2012, with a primary discharge diagnosis of acute asthma exacerbation or status asthmaticus. The study was approved by the Institutional Review Board at the University of Alabama at Birmingham. A list of eligible patients was obtained from an internal database query for all patients in the time period with a primary ICD-9-CM (*International Classification of Diseases, Version 9, Clinical Modification*) discharge diagnosis code for asthma (493.X). The primary investigator (SN) manually reviewed charts with a data extraction checklist and entered results into a Microsoft Excel spreadsheet.

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Data was collected on: date of birth, gender, date of admission, date of discharge, ED triage vital signs, history of fever, history of abdominal pain, number of CXRs ordered, location of CXR ordering (ED versus inpatient), radiologists’ reading of CXRs, administration of intravenous magnesium, administration of continuous nebulized albuterol, active antibiotic treatment at time of ED visit, timing/duration of all antibiotics given during hospitalization, length of stay (LOS), and readmissions for asthma exacerbation or status asthmaticus within 30 days of discharge. We defined LOS as the time from arrival to the inpatient floor to the time of discharge from the hospital.

Patients were excluded if they:

- (1) did not have any details of the ED visit in their chart,
- (2) were taking antibiotics at the time of the ED visit,
- (3) received continuous albuterol or intravenous magnesium during ED or inpatient stay,
- (4) or had another chronic disease affecting lung function. Specifically, we excluded patients with ICD-9 discharge codes for sickle cell disease (282.X), bronchopulmonary dysplasia (747.X, 748.X, 770.7), cerebral palsy (343.X), immunodeficiency (279.X) or congenital heart disease (745.X, 746.X).

Due to generally low rates of positive blood or sputum cultures in children with community-acquired pneumonia, we defined pneumonia based on the clinician’s treatment decisions, with the following criteria:

- (1) any initiation of antibiotic therapy in the ED or during the hospitalization,
- (2) no other infectious diagnosis identified from review of the patient notes, and
- (3) continuation of antibiotics upon discharge.

All CXRs were interpreted by pediatric radiologists. CXRs were called “positive” if the reading included findings of pneumothorax or pneumomediastinum, or if the CXR led to a clinical diagnosis of pneumonia, as determined by the criteria listed above. CXRs were called “negative” if the interpretation included findings of atelectasis or other inflammatory changes that did not lead to a therapeutic course of antibiotics.

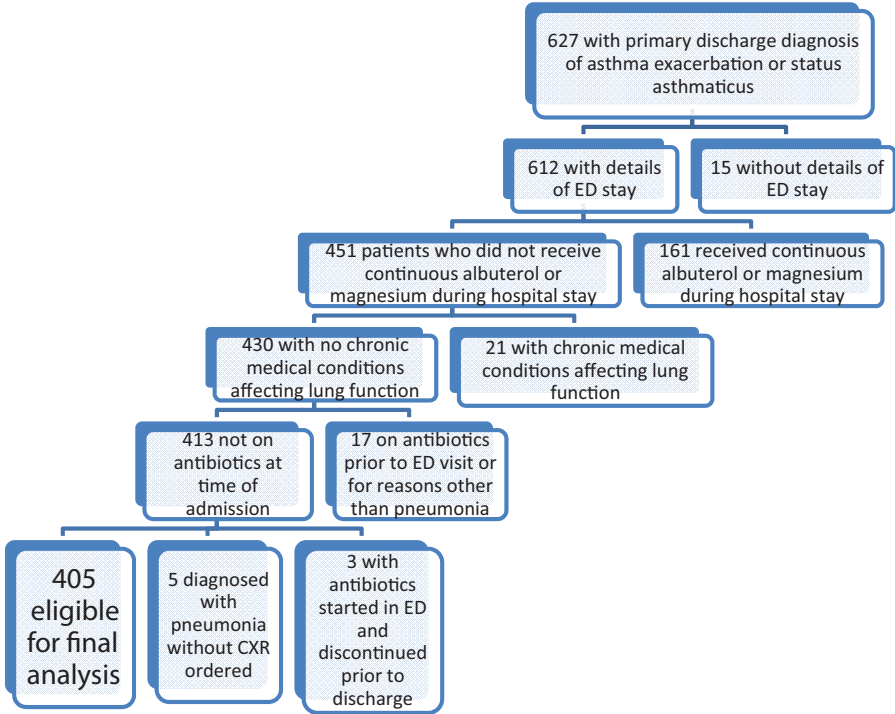
Ordering of radiographs and initiation of antibiotics were at the discretion of the treating physician. Fisher’s exact tests were used to compare ratios. T-tests were used to compare continuous values.

Results

Of the 627 patients admitted with asthma exacerbation or status asthmaticus during the study period, 405 were eligible for study analysis (Table 1). Mean age of all study subjects was 6.8 ± 0.4 years. There were 204 CXRs performed on 180 patients (40% of eligible patients). Roughly three-fourths of these patients (143, 74%) had CXR’s performed as part of the ED visit. Subjects were more likely to have CXRs performed if they were ≤ 4 years of age, had fever either in the ED or at home, or had triage oxygen saturations $\leq 92\%$ on room air ($p < 0.05$ for all; Table 2).

Of the 180 subjects with CXRs performed, 18 (10%) had positive results. This included nine cases of “atelectasis” or “atelectasis versus infiltrate” that were treated with antibiotics, six cases of radiographic pneumonia (a reading of “consolidation” or “infiltrate”), and three cases of air leak (Table 3). Eleven of the 15 study subjects diagnosed with pneumonia were started on antibiotics in the ED. Eight of these 11 patients had length of stay (LOS) less than 48 h, the

Table 1. Table of exclusions.



four subjects started on antibiotics after hospital day 1 all had LOS greater than 72 h.

CXR's ordered in the ED were positive 11.2% of the time (16/143) compared to 21.3% (13/61) of inpatient CXR's (OR 2.15 [0.89–5.15], NS). Odds of a positive CXR were increased with ED temperature $\geq 38.4^\circ\text{C}$ ($p < 0.05$) and triage oxygen saturations $\leq 92\%$ on room air ($p < 0.01$), but age and history of fever were not significant (Table 4).

Among the 405 hospitalizations that met inclusion criteria, there were nine readmissions within 30 days of discharge. Two of these patients were diagnosed with pneumonia on their readmission, but both of them had chest radiographs on the first admission that were read as negative by the attending radiologist.

Discussion

This retrospective analysis showed a low incidence of air leak or pneumonia in non-critically ill inpatients admitted with acute asthma exacerbation. We report similar rates of CXR ordering to Davies' UK study [3], which assessed children over 1 year of age admitted with acute wheeze and found an increase in ordering frequency from 33% in 1998 to 43% in

2005. Given our focus on patients with a discharge diagnosis of asthma, we would have expected a slightly lower CXR ordering frequency in our study, since these patients often have an established chronic condition to explain acute wheeze.

Based on our data, the yield of CXR's for asthmatics requiring inpatient care is very low. In 1982, Rushton observed no difference between CXR results of asthmatic children successfully treated as outpatients and those requiring hospitalization [5]. Our manual chart review suggests that ordering of CXR's in the ED may have an influence on committing a patient to a course of oral antibiotics. Pneumonia was primarily diagnosed in two subsets of patients in our study. One subset was started on antibiotics in the ED and had LOS less than 48 h, suggesting that the respiratory distress was quick to resolve. This points more to a diagnosis of asthma with significant atelectasis in these patients. Another subset of patients had complicated hospital courses and length of stay greater than 72 h, which likely influenced inpatient CXR ordering and antibiotic initiation.

Fever in the ED was strongly associated with CXR ordering in our study, similar to observations of ED patients with asthma, independent of disposition [4]. CXR's were also

Table 2. Factors associated with CXR ordering.

Factor	Ordered (<i>n</i> = 180)	Not ordered (<i>n</i> = 225)	Odds ratio (95% CI)
Age ≤ 4 years*	63 (35%)	43 (21%)	2.3 (1.4–3.7)
Fever ($\geq 38.4^\circ\text{C}$) at home or in ED	85 (47%)	37 (16%)	4.5 (2.8–7.4)
History of abdominal pain	21 (12%)	24 (11%)	1.1 (0.6–2.1)
Maximum ED temperature $\geq 38.4^\circ\text{C}$	20 (11%)	10 (4%)	2.9 (1.1–6.4)
Triage oxygen saturation $\leq 92\%$	101 (56%)	95 (42%)	1.8 (1.2–2.7)

CI = confidence interval.

*The only age cut-off with statistically significant odds ratio for ordering of CXR's was for children 4 years or younger.

Table 4. Factors associated with positive CXR results.

Factor	Positive (<i>n</i> = 18)	Negative (<i>n</i> = 162)	Odds ratio (95% CI)
Fever ($\geq 38.4^\circ\text{C}$) at home or in ED	10 (56%)	75 (46%)	1.5 (0.5–4.3)
History of abdominal pain	2 (11%)	19 (12%)	0.9 (0.1–4.8)
Maximum ED temperature $\geq 38.4^\circ\text{C}$	5 (28%)	15 (9%)	3.8 (1.0–13.6)
Triage oxygen saturation $\leq 92\%$	11 (61%)	44 (27%)	4.2 (1.4–13.0)

CI = confidence interval.

There were no significant age cut-offs for positive versus negative CXR's.

Table 3. Case summaries of 18 patients with positive CXR's.

	Age, yrs	Length of stay, days	CXR done total	CXR done in ED	CXR reading by radiologist	ED max temp ($^\circ\text{C}$)	Triage oxygen saturation	History of fever?	History of abdominal pain?	Antibiotics given (hospital day of initiation)
1	6.4	1.5	2	1	Pneumomediastinum	36.4	94	No	No	N/A
2	7.4	1.9	3	1	Pneumomediastinum	37.2	87	No	No	N/A
3	11.9	2.4	2	1	Pneumothorax and pneumomediastinum	36.9	92	No	No	N/A
4	2.4	4.8	3	1	Pneumonia	39.4	86	No	No	Azt (1)
5	3.9	1.8	1	1	Pneumonia	37.6	95	Yes	No	Azt (1)
6	7.9	4.5	1	0	Pneumonia	37.6	93	No	No	Amox (3)
7	8.2	1.4	1	1	Pneumonia	37.2	93	No	Yes	Azt (1)
8	9.4	4.6	2	1	Pneumonia	36.2	88	No	No	Azt (3)
9	11.7	1.6	1	0	Pneumonia	38.1	91	No	No	Azt (1)
10	2.1	2.3	1	1	Atelectasis versus infiltrate	38.7	89	Yes	No	Clin (1)
11	2.7	1.0	1	1	Atelectasis versus infiltrate	37.3	96	No	No	Pip/Tazo (1), Amox (1)
12	3.2	5.8	2	1	Atelectasis versus infiltrate	37.1	86	Yes	No	Azt (5)
13	3.6	3.7	1	1	Atelectasis versus infiltrate	38.4	83	Yes	No	Ctx (1), Amox (2)
14	4.4	3.9	2	1	Atelectasis versus infiltrate	36.9	90	Yes	Yes	Azt (2)
15	5.2	1.5	1	1	Atelectasis versus infiltrate	38.4	91	Yes	No	Azt (1)
16	9.1	1.5	2	1	Atelectasis versus infiltrate	37.4	89	Yes	No	Azt (1)
17	9.2	1.7	2	1	Atelectasis versus infiltrate	39.4	82	Yes	No	Ctx (1), Amox (2)
18	14.1	1.1	1	1	Atelectasis versus infiltrate	36.7	96	No	No	Azt (1)

Amox = amoxicillin, Azt = azithromycin, Clin = clindamycin, Ctx = ceftriaxone, Pip/Tazo = piperacillin/tazobactam.

ordered more often in patients 4 years or younger, despite our finding no association with age and likelihood of abnormal CXR findings. Abnormal CXR findings in hospitalized children were associated with ED triage hypoxia, as previously reported in multiple studies [7–9], but not with a history of fever or with abdominal pain, as was noted by Mathews in a cohort of children with wheeze [7].

Two ED-based quality improvement initiatives have yielded modest reductions in CXR ordering rates by outlining criteria for necessity of CXRs [11,12]. The same methodology could be applied to pediatric inpatients in this study; of the nine patients with radiographic pneumonia or air leak, all had an ED triage oxygen saturation $\leq 95\%$. Restricting CXRs to these parameters would have prevented ordering in 48 (30%) of the 162 subjects with negative CXRs while missing only patient with a treatment-altering CXR (subject 11 from Table 3, a 2-year-old with equivocal radiologic diagnosis and no history of fever). Adding a second criterion of poor response to therapy, namely hospital stay >48 h, would have prevented CXR ordering in an additional 82 subjects, eliminating negative CXRs from 80% (130 of 162) this study without missing a treatment-altering CXR.

We found that nine of 15 cases of pneumonia were based on inconclusive or equivocal CXR readings. Determining bacterial versus viral etiology for an abnormal chest radiograph remains a challenge, with studies finding very low rates of positive serologies in wheezing children [13]. If radiographs had not been ordered on these patients, the outcomes may have been different, depending on the etiology of disease. Cases of viral pneumonia would have gradually resolved without treatment, and cases of air leak would have also resolved with oxygen supplementation and underlying treatment of bronchospasm [6,8,10].

Alveolar infiltrates have been shown to be more likely than interstitial infiltrates to have a bacterial source in children [14], but after a systematic literature review, Lynch suggested that “there was no gold standard” to distinguish between bacterial and viral pneumonia [15]. These observations raise the question of whether the decision to treat pneumonia is increasingly based on clinical findings and is independent of the CXR reading. The most recent Infectious Disease Society of America guidelines on pediatric community-acquired pneumonia echo this sentiment, suggesting that “chest radiographs are not necessary... in patients well enough to be treated in the outpatient setting” [16].

We did not have complete follow-up data regarding ED re-evaluations for patients without chest radiographs ordered, but our two missed diagnoses of pneumonia both presented as late complications after the patients had met the clinician’s discharge criteria for the initial asthma exacerbation. Both patients had preliminarily negative radiographs during the first admission, suggesting that close supervision should allow an undiagnosed pneumonia to declare itself prior to discharge or at outpatient follow-up, without needing to routinely image every child admitted with acute asthma exacerbation.

The limitations of this study were mainly in its retrospective nature and inability to establish uniform criteria for the diagnosis or treatment of pneumonia. Some patients with a history of asthma could have been missed in the accrual if

they had pneumonia, and not asthma exacerbation, listed as the primary discharge diagnosis. Because our diagnosis criteria were purely clinical, we may have overestimated the number of diagnoses of bacterial pneumonia. Patients with prolonged atelectasis or hypoxemia from viral pneumonia could have been treated unnecessarily with systemic antibiotics and diagnosed with bacterial pneumonia without confirmatory microbiologic or serologic data.

Conclusions

The overwhelming majority of CXRs in non-critical pediatric asthma patients do not show evidence of pneumonia or airleak. Younger age, history of fever and low oxygen saturations all increased the likelihood of ordering a CXR. Fever $>38.4^\circ\text{C}$ in the ED and oxygen saturations $\leq 92\%$ at ED triage had the highest association with positive CXR. Future directions of study include a quality improvement and education initiative to reduce unnecessary CXRs and to encourage observation without antibiotics in equivocal cases of radiographic pneumonia.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Contributions

Dr. Narayanan conceived and designed this study, analyzed and interpreted data, drafted the article, and gave final approval of the version to be published.

Dr. Magruder made contributions to study conception and design, interpretation of data, and revised the article for intellectual content.

Dr. Walley made contributions to study conception and design, and revised the article for intellectual content.

Mr. Powers acquired data for the study and made contributions to analysis and interpretation of the data.

Dr. Wall made contributions to study conception and design, acquisition of data, revised the article for intellectual content, and contributed to final approval of the version to be published.

References

1. British Thoracic Society, Scottish Intercollegiate Guidelines Network. British guideline on the management of asthma. Thorax 2008;63:iv, 1–121.
2. National Heart, Lung, and Blood Institute. National Asthma Education Program Expert Panel Report 3. Guidelines for the diagnosis and management of asthma. Section 5, Managing Exacerbations of Asthma. National Institutes of Health, 2007. Available at: <http://www.nhlbi.nih.gov/guidelines/asthma/asthgdln.pdf> [last accessed 1 Sep 2013].
3. 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;93:952–958.
4. Stanley RM, Teach SJ, Mann NC, Alpern ER, Gerardi MJ, Mahajan PV, Chamberlain JM. Variation in ancillary testing among pediatric asthma patients seen in emergency departments. Acad Emerg Med 2007;14:532–538.
5. Rushton AR. The role of the chest radiograph in the management of childhood asthma. Clin Pediatr (Phila) 1982;21:325–328.
6. Brooks LJ. Significance of roentgenographic abnormalities in children hospitalized for asthma. Chest 1982;3:315–318.

7. Mathews B, Shah S, Cleveland RH, Lee EY, Bachur RG, Neuman MI. Clinical predictors of pneumonia among children with wheezing. *Pediatrics* 2009;124:e29–e36.
8. Gershel JC, Goldman HS, Stein RE, Shelov SP, Ziprkowski M. The usefulness of chest radiographs in first asthma attacks. *N Engl J Med* 1983;309:336–339.
9. Roback MG, Dreitlein DA. Chest radiograph in the evaluation of first time wheezing episodes: review of current clinical practice and efficacy. *Pediatr Emerg Care* 1998;14:181–184.
10. Stack AM, Caputo GL. Pneumomediastinum in childhood asthma. *Pediatr Emerg Care* 1996;12:98–101.
11. Gentile NT, Ufberg J, Barnum M, McHugh M, Karras D. Guidelines reduce X-ray and blood gas utilization in acute asthma. *Am J Emer Med* 2003;21:451–453.
12. 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;41:107–111.
13. Lehtinen P, Jartti T, Virkki R, Vuorinen T, Leinonen M, Peltola V, Ruohola A, Ruuskanen O. Bacterial coinfections in children with viral wheezing. *Eur J Clin Microbiol Infect Dis* 2006;25:463–469.
14. Virkki R, Juven T, Rikalainen H, Svedström E, Mertsola J, Ruuskanen O. Differentiation of bacterial and viral pneumonia in children. *Thorax* 2002;57:438–41.
15. Lynch T, Bialy L, Kellner JD, Osmond MH, Klassen TP, Durec T, Leicht R, Johnson DW. A systematic review on the diagnosis of pediatric bacterial pneumonia: when gold is bronze. *PLoS One* 2010;5:e11989.
16. Bradley JS, Byington CL, Shah SS, Alverson B, Carter ER, Harrison C, Kaplan SL, et al. The management of community-acquired pneumonia in infants and children older than 3 months of age: clinical practice guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America. *Clin Infect Dis* 2011;53:e25–e76.