Physician Assessment of the Likelihood of Pneumonia in a Pediatric Emergency Department

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Background: The value of physical examination findings in the diagnosis of pneumonia in children may be limited, and the accuracy of physicians in predicting pneumonia is not known.

Objective: We sought to determine the correlation between physicians' assessment of the likelihood of pneumonia and radiographic presence of pneumonia.

Methods: Prospective observational study of children 21 years or younger presenting to a pediatric emergency department, who had a chest radiography performed for suspicion of pneumonia. Physicians recorded clinical findings and likelihood of pneumonia before obtaining the radiograph. Definite and probable pneumonia was defined by a radiologist's interpretation of the radiograph.

Results: Of 2071 children, 147 (7%) had definite radiographic pneumonia, whereas 321 (15%) had probable or definite pneumonia. Among patients perceived to be at lowest risk for pneumonia (<5% prediction), 4.3% (95% confidence interval [CI], 2.9%–5.7%) had definite pneumonia, and 10.0% (95% CI, 8.3%–12.5%) had probable or definite pneumonia. Among children perceived to be at highest risk for pneumonia (>75% prediction), 30.6% (95% CI, 15.5%–45.6%) had definite pneumonia, and 52.8% (95% CI, 37.7%–70.3%) had probable or definite pneumonia. Physicians' estimates of the likelihood of pneumonia were positively correlated with the rate of definite (Spearman $\rho = 0.15$, $P < 0.001$) and probable or definite radiographic pneumonia (Spearman $\rho = 0.19$, $P < 0.001$).

Conclusions: With some overestimation, physicians' assessment of the likelihood of pneumonia correlates well with radiographic diagnosis of pneumonia.

Key Words: pneumonia, radiograph, chest radiograph

The decision to order a chest radiograph (CXR) to evaluate for pneumonia in a child is typically based on historical factors, such as the presence of fever and duration of cough, as well as physical examination findings, such as the presence of focal rales or decreased breath sounds. A child with fever and cough for 3 days who has focal rales on examination will probably be judged by a physician to be very likely to have pneumonia, whereas a child without fever and without focal findings on auscultatory examination will most likely be presumed to be at low risk of having radiographic pneumonia. Thus, the decision to initiate antimicrobial therapy is often based on clinical suspicion, rather than radiographic studies, particularly in resource poor settings.[1–6]

Studies in adults have demonstrated that certain physical examination findings, such as focal rales and decreased breath sounds, have very good sensitivity in the diagnosis of pneumonia.[7,8] There are a paucity of data investigating test characteristics of historical and examination findings in the evaluation of pneumonia in children.[1,2,4] In addition, a small proportion of children, without tachypnea, and without auscultatory findings on examination, will have radiographic pneumonia (previously termed *occult pneumonia*).[9,10] To our knowledge, there are no studies that assess the correlation between the perceived likelihood of pneumonia, as judged by the physician, and the rate of radiographic pneumonia in children.

We sought to (1) determine the correlation between physicians' assessment of the likelihood of pneumonia and the radiographic presence of pneumonia among children presenting to the emergency department (ED) in whom a CXR was obtained and (2) investigate whether certain patient characteristics and/or indications for obtaining a CXR altered the assessment of pneumonia risk. Lastly, among patients in whom a radiograph was obtained because of the presence of auscultatory findings, we sought to determine the accuracy of physicians' assessment of the likelihood of pneumonia.

METHODS

As part of a prospective observational study to determine the clinical utility of chest radiography among children presenting to a pediatric ED, we asked physicians to indicate the likelihood of pneumonia, for every patient in whom a CXR was obtained.[11] The study was conducted during an 18-month period (November 2006 to July 2008) in a large urban pediatric ED with approximately 56,000 visits annually. Patients younger than 22 years were eligible for inclusion in the study if a CXR was obtained for suspicion of pneumonia. Subjects were excluded if they received a CXR for an indication other than the evaluation for pneumonia (eg, foreign body aspiration, trauma, cardiac disease, pneumothorax). In addition, patients with chronic respiratory illness, such as cystic fibrosis, or any other illness that would increase the risk of pneumonia, such as sickle cell disease or immunosuppression, were also excluded.

Data were collected via check box questionnaires not allowing a free narrative. All physicians in the ED were asked to complete a questionnaire for each patient in whom a CXR was obtained. Physicians completed a questionnaire before obtaining the CXR. Each form was placed in a secure lockbox. To ensure accurate results, questionnaires completed by trainees (pediatric emergency fellows and residents) required review by the supervising attending physician before depositing the form.

We asked physicians to indicate the likelihood of pneumonia based on their evaluation and before knowledge of CXR results. Responses included the following choices: less than 5%, 5% to 10%, 11% to 20%, 21% to 50%, 51% to 75%, and greater

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than 75%. Physicians were also asked to select the indication for obtaining the CXR (eg, height of fever, duration of fever, duration of cough, respiratory distress, presence of auscultatory findings, elevated white blood cell count, or others) and were able to select more than 1 indication. The questionnaire asked for specific findings on physical examination, which included the presence of retractions, grunting, and tachypnea. Tachypnea was defined in 2 separate ways: (1) physician-assessed tachypnea, which was simply a check box on the study questionnaire, and (2) age-specific tachypnea defined by respiratory rate (RR) at triage (RR ≥ 60 breaths per minute for children <2 years, RR ≥ 50 breaths per minute for children 2–4.9 years, RR ≥ 30 breaths per minute for children 5–9.9 years, and ≥25 breaths per minute for children 10–21 years) without any adjustment for fever or agitation of the child at the time of the measurement.

Specific auscultatory findings listed on the study questionnaire included focal decreased breath sounds, rales, and wheezing. For the latter 2 findings, we asked physicians to indicate whether the finding was focal in one specific lung region or diffuse. Further details of the study questionnaire have previously been described.[11]

Electronic medical records were reviewed to obtain demographic information, vital signs, treatment administered in the ED, disposition, and outcome. In addition, the final CXR report was obtained from the electronic medical record. All CXRs at our institution are interpreted by a board-certified pediatric radiologist. We classified the CXRs into 3 groups: (1) definite pneumonia, (2) negative, or (3) equivocal for the presence of radiographic pneumonia. A radiographic diagnosis of definite pneumonia was designated if a CXR report listed the presence of infiltrate, consolidation, or pneumonia and was considered negative if there was no mention of these findings. A radiograph was assessed to be equivocal if there was mention of "atelectasis versus pneumonia (and/or) infiltrate" or "cannot exclude pneumonia." Patients with equivocal or definite findings of pneumonia are herein defined as probable or definite pneumonia.

We compared the assessed likelihood of pneumonia by the ordering physician, to the actual rate of definite, and probable or definite radiographic pneumonia. For the 4 most common indications for ordering a CXR, we compared the physician-assessed likelihood of pneumonia to the radiographic diagnoses. Lastly, for CXRs ordered for the indication of "auscultatory findings," we compared the physicians' assessment of likelihood of pneumonia to the actual rates of pneumonia, for each specific auscultatory finding.

Data analysis was performed with SPSS (Statistical Package for Social Sciences, Version 15; SPSS, Inc, Chicago, IL). The relationship between the predicted probability of pneumonia and radiographic pneumonia was assessed using the Spearman rank correlation coefficient (ρ); $P ≤ 0.05$ was considered significant.

We audited the electronic medical records of 10% of patients in whom a CXR was ordered during the study period to assess whether our study population was representative of all children in whom a CXR was obtained.

The study was approved by the institutional review board. Data collection was compliant with the Health Insurance Portability and Accountability Act of 1996.

RESULTS

Study forms were completed for 2415 patients. Of these, 157 patients were excluded because the probability of pneumonia was not recorded by the physician, 26 patients were older than 21 years, and 161 were excluded because of a condition predisposing towards pneumonia. Two thousand seventy-one patients met inclusion criteria during the 18-month study period. On the basis of an audit of radiographs ordered in the ED, 51% percent of eligible patients were enrolled. The rate of pneumonia between enrolled patients and eligible but not enrolled patients did not differ.

The median age of study patients was 2.3 years (interquartile range [IQR], 0.8–5.3 years), and median triage temperature was 37.5°C (IQR, 36.8–38.4°C); other demographic characteristics of our study population are shown in Table 1. A total of 147 (7.1%) children were determined to have "definite pneumonia" on the basis of the final radiology reading and 321 (15.5%) had "definite or probable pneumonia." Overall, 27.8% of patients received an antibiotic in the ED, of which 17.9% were administered for the diagnosis of pneumonia. The proportion of patients treated with an antibiotic is more consistent with the population defined as having either probable or definite pneumonia rather than definite pneumonia alone. Of these patients, 22% were hospitalized, and 34.9% of patients with definite pneumonia were hospitalized.

Table 2 shows the physicians' assessment of the likelihood of pneumonia compared with the radiographic diagnosis of pneumonia. Among the group of children believed to be at the lowest risk of pneumonia (estimated risk of pneumonia <5%), the corresponding rate of definite pneumonia and probable or definite pneumonia was quite low (4.3% [95% confidence

TABLE 1. Demographics of the Study Population (n = 2071)

Characteristic	n (%)
Age, yr	
<2	949 (45.8)
2–4.9	552 (26.7)
5–9.9	334 (16.1)
10–21.9	236 (11.4)
Males	1117 (53.9)
Triage temperature, °C	
<38	1341 (64.9)
38.0–38.9	431 (20.8)
39.0–39.9	252 (12.2)
≥40	43 (2.1)
Age-specific tachypnea	293 (14.1)
Age <2 yr (RR ≥60 breaths per minute)	108 (11.5)
Age 2–4.9 yr (RR ≥50 breaths per minute)	41 (7.5)
Age 5–9.9 yr (RR ≥30 breaths per minute)	89 (26.8)
Age 10–21 yr (RR ≥25 breaths per minute)	55 (23.3)
Triage oxygen saturation, %	
<90	30 (1.4)
90–93	108 (5.2)
94–96	418 (20.2)
>96	1348 (65.1)
Radiographic pneumonia	
Definite pneumonia	147 (7.1)
Probable or definite pneumonia	321 (15.5)
Antibiotic administered in ED	576 (27.8)
Antibiotic administered for diagnosis of pneumonia	370 (17.9)
Admitted to hospital, %	456 (22.0)
Definite pneumonia	51 (34.9)
Probable or definite pneumonia	104 (32.5)

TABLE 2. Evaluation of the Likelihood of Pneumonia (n = 2071)

Physicians' Assessment of Likelihood of Pneumonia	Definite Pneumonia (n = 147, 7.1%), % (95% CI)	Probable or Definite Pneumonia (n = 321, 15.5%), % (95% CI)	ED Discharge Diagnosis of Pneumonia, % (95% CI)
<5%	4.3 (2.9–5.7)	10.0 (8.3–12.5)	9.3 (7.3–11.3)
5%–10%	6.5 (4.7–8.3)	14.9 (12.3–17.6)	18.0 (15.1–20.8)
11%–20%	9.1 (5.6–12.6)	20.9 (15.9–25.7)	25.0 (19.8–30.2)
21%–50%	16.4 (9.8–23.0)	24.6 (17.0–32.2)	38.8 (29.4–46.6)
50%–75%	15.2 (6.5–23.8)	36.4 (24.8–48.0)	54.8 (42.0–66.0)
>75%	30.6 (15.5–45.6)	52.8 (37.7–70.3)	75.8 (60.9–89.2)

interval {CI}, 2.9%–5.7%] and 10.0% [95% CI, 8.3%–12.5%], respectively). Children assessed to be at the highest risk of pneumonia (estimated >75%) had a high rate of radiographic pneumonia (30.6% [95% CI, 15.5%–45.6%] with definite radiographic pneumonia and 52.8% [95% CI, 37.7%–70.3%] with probable or definite pneumonia). Physicians' estimates of the likelihood of pneumonia were positively correlated with the rate of definite (Spearman ρ = 0.15, P < 0.001) and probable or definite radiographic pneumonia (Spearman ρ = 0.19, P < 0.001). The rate of pneumonia diagnosis by ED provider parallels the rate of probable or definite radiographic pneumo-

nia and is positively correlated with physicians' estimated rate of pneumonia (Spearman ρ = 0.28, P < 0.001).

The most common indication for obtaining a CXR was for a prolonged duration of cough (n = 672, 32.4%). Among these children, 8.3% (95% CI, 6.1%–10.2%) had definite pneumonia and 17.2% (95% CI, 14.5%–20.3%) had probable or definite pneumonia (Table 3). The rates of definite and probable or definite pneumonia for other common indications are as follows: height of fever (7.4% and 17.2%, respectively), duration of fever (10.4% and 22.9%, respectively), and the presence of auscultatory findings (8.1% and 19.2%, respectively). Among children

TABLE 3. Assessment of Pneumonia Risk Based on Indication for Obtaining CXR

Physicians' Assessment of Likelihood of Pneumonia by Indication for Ordering Radiograph*	n	Definite Pneumonia, n (%) [95% CI]	Probable or Definite Pneumonia, n (%) [95% CI]
Height of fever	645	48 (7.4%) [5.4%–9.5%]	111 (17.2%) [14.3%–20.1%]
<5%	209	10 (4.8)	29 (13.9)
5%–10%	256	18 (7.0)	34 (13.3)
11%–20%	96	5 (2.2)	20 (20.8)
21%–50%	48	5 (10.4)	9 (18.8)
51%–75%	28	6 (21.4)	13 (46.4)
>75%	8	4 (50.0)	6 (75.0)
Auscultatory findings	605	49 (8.1%) [5.9%–10.3%]	116 (19.2%) [16.0%–22.3%]
<5%	113	3 (2.7)	11 (9.7)
5%–10%	235	12 (5.1)	36 (15.3)
11%–20%	120	8 (6.7)	27 (22.5)
21%–50%	66	9 (13.6)	10 (15.2)
51%–75%	44	8 (18.2)	18 (40.1)
>75%	27	9 (33.3)	14 (51.9)
Duration of fever	480	50 (10.4%) [7.7%–13.1%]	110 (22.9%) [19.2%–26.7%]
<5%	146	9 (6.2)	24 (16.4)
5%–10%	191	20 (10.5)	38 (19.9)
11%–20%	63	6 (9.5)	18 (28.6)
21%–50%	42	6 (14.3)	12 (28.6)
51%–75%	26	3 (11.5)	10 (38.5)
>75%	12	6 (50.0)	8 (66.7)
Duration of cough	672	55 (8.3%) [6.1%–10.2%]	117 (17.2%) [14.5%–20.3%]
<5%	259	14 (5.4)	30 (11.6)
5%–10%	243	21 (8.6)	39 (16.0)
11%–20%	90	5 (5.6)	21 (23.3)
21%–50%	46	6 (13.0)	9 (19.6)
51%–75%	19	2 (10.5)	9 (47.4)
>75%	15	7 (46.7)	9 (60.0)

*Indications for obtaining a CXR are not mutually exclusive (ie, physicians could select >1 indication).

TABLE 4A. Assessment of *Definite* Pneumonia Risk Based on Individual Examination Finding

Assessment of Likelihood of Pneumonia	% With Definite Pneumonia by Specific Examination Finding						
	Retractions	Tachypnea		Focal Decreased Breath Sounds	Rales	Focal Rales	Focal Wheeze
		Physician-Assessed Tachypnea	Age-Defined Tachypnea				
<5%	7/170 (4.1)	7/206 (3.4)	2/98 (2.0)	0/30 (0.0)	1/140 (0.7)	1/33 (3.0)	0/18 (0.0)
5%–10%	9/144 (6.3)	18/243 (7.4)	8/101 (7.9)	5/91 (5.5)	13/211 (6.2)	9/111 (8.1)	2/21 (9.5)
11%–20%	5/53 (9.4)	9/88 (10.2)	7/41 (17.1)	6/49 (12.2)	9/119 (7.6)	7/65 (10.8)	1/12 (8.3)
21%–50%	4/30 (13.3)	9/49 (18.4)	4/27 (14.8)	6/26 (23.1)	10/71 (14.1)	8/42 (19.0)	2/10 (20.0)
51%–75%	2/17 (11.8)	4/32 (12.5)	3/18 (16.7)	4/27 (14.8)	8/43 (18.6)	7/34 (20.6)	0/2 (0.0)
>75%	2/7 (28.6)	4/10 (40.0)	2/8 (30.6)	5/11 (45.5)	5/26 (19.2)	5/18 (27.8)	0/1 (0.0)

who had a CXR obtained for the indication of "first episode of wheeze," the rate of pneumonia was very low (definite pneumonia, 1.6%; probable or definite pneumonia, 9.2%).

A total of 605 (29.2%) patients had "auscultatory findings" as one of their primary indications for obtaining a CXR. Among this group of children, 8.1% were diagnosed with definite pneumonia, and 19.2% were diagnosed with probable or definite pneumonia (Tables 4A and 4B, respectively). Children with focal rales on examination who were perceived to be at low risk of pneumonia (<5%) were unlikely to have radiographic pneumonia (definite pneumonia, 3.0%; probable or definite pneumonia, 3.0%). Children with focal rales, who were perceived to be at highest risk of pneumonia (>75%), were likely to have pneumonia (definite pneumonia, 27.8%; probable or definite pneumonia, 44.4%). Among children who had a CXR obtained for the presence of focal wheeze on auscultatory examination, the overall rate of pneumonia was quite low (definite pneumonia, 7.8%; probable or definite pneumonia, 12.5%).

Among children younger than 2 years perceived to be at the lowest risk of pneumonia (<5%), the actual rate of pneumonia was low (definite pneumonia, 2%, probable or definite pneumonia, 8%); however, even for those predicted to be at high risk of pneumonia (>50%), the actual rate of pneumonia was also low (definite pneumonia, 0%; probable or definite pneumonia, 24%). The number of young children judged to be at high risk of pneumonia was low (n = 21). Among older children (>10 years), those judged to have greater than 50% risk of pneumonia did have a high rate of radiographic pneumonia (definite pneumonia, 30%; probable or definite pneumonia, 45%). Among patients with right-sided radiographic pneumonia, only 26% had auscu-

latory findings localized to the right side of the chest (3% had focal left-sided findings, 13% diffused examination findings, and 57% had no auscultatory findings on examination); similarly, only 24% of patients with left-sided radiographic pneumonia had focal left-sided auscultatory findings.

DISCUSSION

The diagnosis of pneumonia can be challenging as there is often a poor correlation between physical examination findings and radiographic pneumonia, particularly in children.[6,12,13] In addition, there is much inherent variability in the practice of ordering a radiograph for a child with suspicion of pneumonia. In our study, we observed that the physicians' assessment of the likelihood of pneumonia correlated with the radiographic diagnosis of pneumonia. We observed that the most common indications for ordering a CXR in children in the ED setting include the height and duration of fever, prolonged duration of cough, and the presence of auscultatory findings. For each of these indications, the rate of radiographic pneumonia correlated with clinical impression of the likelihood of pneumonia.

For children in whom a radiograph was obtained primarily for the presence of auscultatory findings on examination, the estimation of pneumonia risk varied based on the examination finding which prompted the physician to order the radiograph. For certain examination findings such as focal rales and focal decreased breath sounds, the perceived risk of pneumonia closely paralleled the rate of radiographic pneumonia. However, for patients who had a CXR obtained for the presence of focal wheeze on examination, the actual rate of pneumonia was quite low for all categories of assessed pneumonia risk.

TABLE 4B. Assessment of *Probable or Definite* Pneumonia Risk Based on Examination Findings

Assessment of Likelihood of Pneumonia	% With Probable or Definite Pneumonia by Specific Examination Finding						
	Retractions	Tachypnea		Focal Decreased Breath Sounds	Rales	Focal Rales	Focal Wheeze
		Physician-Assessed Tachypnea	Age-Defined Tachypnea				
<5%	21/170 (1.2)	22/206 (10.7)	11/98 (11.2)	5/30 (16.7)	8/140 (5.7)	1/33 (3.0)	0/18 (0.0)
5%–10%	25/144 (17.4)	36/243 (14.8)	16/101 (15.8)	12/91 (13.2)	36/211 (17.1)	21/111 (18.9)	4/21 (19.0)
11%–20%	7/53 (13.2)	18/88 (20.5)	11/41 (26.8)	10/49 (20.4)	25/119 (21.0)	18/65 (27.7)	2/12 (16.7)
21%–50%	7/30 (23.3)	12/49 (24.5)	7/27 (25.9)	10/26 (38.5)	15/71 (21.1)	10/42 (23.8)	2/10 (20.0)
51%–75%	5/17 (29.4)	14/32 (43.8)	8/18 (44.4)	12/27 (44.4)	17/43 (39.5)	15/34 (44.1)	0/2 (0.0)
>75%	4/7 (57.1)	8/10 (80.0)	7/8 (87.5)	7/11 (63.6)	11/26 (42.3)	8/18 (44.4)	0/1 (0.0)

Compared with infants and young children, the estimated rate of pneumonia among older children and adolescents more closely paralleled the actual rate of radiographic pneumonia. This may reflect the inherent challenges in obtaining an accurate history of illness among preverbal children and the difficulties in detecting subtle physical examination findings in younger children.[2,14] It is interesting to note that only 25% of children had auscultatory findings localized to the correct side of the chest in which radiographic pneumonia is present.

There are limited data investigating specific clinical examination findings or decision rules to help guide physicians to determine which children presenting to the ED require a CXR.[4,13–20] One study in adults found that physicians' clinical impression before obtaining a CXR was a better predictor of radiographic pneumonia than any other combination of signs and symptoms in the ED.[4] This may be influenced by that fact that ED physicians may have a lower threshold to diagnose and treat patients for pneumonia based on the lack of appropriate follow-up, access to radiography, and higher severity of illness than encountered in primary care settings.

There is no criterion standard for the diagnosis of pneumonia in children.[8,12,17,21] Most physicians will treat a child for bacterial pneumonia based on the presence of an infiltrate on a CXR.[2,14,22,23] However, under certain circumstances, such as described with dehydration, a patient with pneumonia may not have an obvious infiltrate on CXR, especially if early in the course of illness.[24] Thus, some physicians will treat patients solely on the presence of physical examination findings, such as focal rales.[8,13,20] Certain auscultatory findings such as focal rales and decreased breath sounds have a moderate sensitivity (70%) for the diagnosis of pneumonia in adults[8]; however, these examination findings may not have a good sensitivity or specificity for the diagnosis of pneumonia in children. Lynch et al[1] found that crackles on examination had a sensitivity of 43% and specificity of 73% for the diagnosis of radiographic pneumonia in children. In their multivariate model, radiographic pneumonia was associated with the following findings on physical examination: fever (odds ratio [OR] = 3.1; 95% CI, 1.7–5.6), decreased breath sounds (OR = 1.5; 95% CI, 1.0–2.2), crackles (OR = 2.0; 95% CI, 1.4–3.0), and tachypnea (OR = 3.0; 95% CI, 1.6–5.9). The prevalence of radiographic pneumonia was 36%, significantly higher than observed in our study. The test characteristics of these examination findings have differed widely in other investigations of radiographic pneumonia in children.[6,7,25,26]

There are several limitations to our study. Only half of the eligible patients who underwent a CXR in the ED setting were enrolled in our study, which may limit the internal validity of our results. However, based on an audit of CXRs performed during the study period, we did not observe a difference in the rate of pneumonia between children included in our study and those children who were eligible for inclusion but not enrolled. Selection bias may have been introduced because we only studied children undergoing chest radiography as part of their medical care. Radiologists in our study were not blinded to the clinical information, which prompted the radiograph to be obtained. Thus, the interpretation of the radiograph may have been biased by the physician who assessed the likelihood of pneumonia. This bias may have been minimized by the fact that radiographs are ordered using a computerized order entry system, in which most requests are made using a default request: "evaluate for pneumonia." Finally, our study was conducted at a single institution, which may limit the generalizability of our results.

In a population of children who undergo radiographic testing to evaluate for pneumonia, physicians' assessment of the likelihood of pneumonia correlates well with radiographic

diagnosis of pneumonia. For each of the common indications for which a radiograph is ordered, physicians accurately are able to identify a population of children at both low risk and high risk of radiographic pneumonia. Overall, physicians accurately but slightly overestimate the risk of pneumonia in children based on historical factors and physical examination findings.

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