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Severity of Childhood Community-Acquired Pneumonia and Chest Radiographic Findings

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Summary. To assess if chest radiographic findings present on admission are associated with severity of childhood community-acquired pneumonia (CAP), a total of 161 children hospitalized with pulmonary infiltrate were enrolled in the study; 48 (30%) patients were excluded because of presence of bilateral chest radiographic alterations (33; 20%) and presence of underlying diseases (15; 9%). According to WHO and BTS criteria, severe CAP was present in 57 (50%) and in 96 (85%) cases, respectively; 29 (26%) were aged less than 1 year. The median age (months) was 22 (mean 24 ± 14, range 2–58). Overall, radiographic finding was right-sided in 77 (68%) cases and the upper lobe was compromised in 36 (32%) cases. By analyzing data stratified to age, the frequency of upper lobe involvement was significantly higher among severe cases (WHO criteria) only for those patients aged $\geq$1 year (13/35 [37%] vs. 7/45 [16%], $P = 0.03$, OR [95% CI] 3.2 [1.1–9.2]). The specificity and positive predictive value of upper lobe involvement for severity among the latter group of patients were 84% (95% CI 70–93%) and 65% (95% CI 41–84%), respectively. No association was found by using the BTS criteria. The admission chest radiography was useful to predict severity of children aged $\geq$1 year hospitalized with CAP. **Pediatr Pulmonol. 2009; 44:249–252.** © 2009 Wiley-Liss, Inc.

Key words: pulmonary infiltrate; pneumonia location; severity predictor.

INTRODUCTION

Community-acquired pneumonia (CAP) is a common cause of outpatient visits and hospital admission for children worldwide.[1] Indeed, CAP is the leading cause of child death in the world and 95% of those deaths occur in developing countries.[2] The usefulness of chest radiograph in diagnosing CAP accurately has been demonstrated.[3] Actually, imaging plays important roles in the diagnosis and treatment of children with CAP which include the exclusion of other causes of symptoms and the evaluation of related complications.[4] Nonetheless, chest radiograph has been found to be not useful in differentiating between bacterial and non-bacterial pneumonia and it has been recommended that it should not be performed routinely in uncomplicated mild acute lower respiratory infection.[5] To the best of our knowledge, radiographic findings have rarely been assessed as predictor of severity in childhood CAP.[6] Therefore, there is scanty information on the possible prognostic value of radiographic evaluation on visits of children with CAP.

In this context, we sought to assess if chest radiographic findings present on admission are associated with severity of children hospitalized with CAP.

MATERIALS AND METHODS

This was a prospective, non-interventional review of CAP cases seen by a pediatrician at Professor Hosannah de Oliveira Pediatric Center, in Salvador, North-east Brazil. From March 2006 to February 2008, by active surveillance, the same researcher (NKK) identified children fulfilling the inclusion criteria and completed a standardized collection form. Inclusion criteria were children aged under 5 years with any of the following findings: history of fever or cough, tachypnea, dyspnea or respiratory distress and presence of a pulmonary infiltrate (PI) or pleural effusion[7] on chest radiograph taken on admission. The age group for inclusion was under 5 years

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because the higher burden of CAP is among these children.[2] The radiological reading was performed by a pediatric radiologist (CAA-N), member of this research project team, blind to clinical information. Children were excluded if there were underlying chronic diseases (anatomic abnormalities of the respiratory tract, immunological defects, progressing neurological conditions, psychomotor retardation, congenital heart disease, hemoglobinopathy), severe malnutrition, other concurrent infections or presence of bilateral PI. The exclusion criteria comprised underlying morbidities and bilateral lung compromising which could lead to a more severe presentation of CAP. Data on demographics, clinical history, and physical examination were recorded. Fever was defined as axillary temperature $>37.5^{\circ}C$,[8] and tachypnea as respiratory rate (RR) ≥ 50 breaths/min in children aged 2–11 months and ≥ 40 breaths/min in children from 12 months of age onwards.[9] Nutritional evaluation was performed by using the software Anthro, version 1.02 (CDC and World Health Organization) and severe malnutrition was defined as *Z*-score for weight-for-age index under -3.00 by using the National Centre for Health Statistics (NCHS-USA) standard.[10]

Chest radiograph changes were registered taking into account the standardized interpretation previously published.[7] The pediatric radiologist registered the radiographic reading in a standardized form and looked for the presence of PI, pleural effusion, consolidation, atelectasis, hyperinflation, abscess, peribronchial thickening, pneumatocele and pneumothorax; each finding was localized as right and or left side as well as upper and or lower lobe. The PI was described as alveolar, interstitial or alveolar-interstitial.

The guidelines used to categorize CAP severity include: presence of chest indrawing, somnolence, seizures, grunting in a calm child, nasal flaring, cyanosis, and inability to drink (WHO guideline)[9] in addition to RR >70 breaths/min for infants, RR >50 breaths/min for older children, difficulty in breathing, dehydration, axillary temperature $>39^{\circ}C$ (BTS guideline).[11]

Statistical Methods

Categorical variables between different groups of children were compared using Chi-square or Fisher's exact test as appropriate. Continuous variables were compared using Student's *t*-test or Mann–Whitney *U*-test as appropriate and the mean difference with the respective 95% confidence interval (CI) was calculated. Specificity and positive predictive value and the respective 95% CI were calculated for variables found to be associated with severity. The statistical tests were two tailed, with a significance level of 0.05. The statistical software SPSS (version 9.0) was used for analysis. Informed consent was obtained from the patient's guardian and the study was approved by the Ethics Committee of the Federal University of Bahia.

RESULTS

A total of 161 children were enrolled in the study, out of which 48 (30%) were excluded: 33 (20%) presented bilateral chest radiographic alteration and 15 (9%) presented the following underlying diseases: sickle cell anemia (4), congenital heart disease (3), liver transplantation (2), severe malnutrition (2), cystic fibrosis (1), thalassemia (1), cleft lip (1), psychomotor retardation (1). Therefore, the study group comprised 113 patients. The median age (months) was 22 (mean 24 ± 14, range 2–58 months) and 29 (26%) patients were aged less than 1 year. There were 58 (51%) males. According to WHO criteria,[9] severe CAP was present in 57 (50%) cases and the severe cases were younger (months) than the non-severe ones (20 ± 13 vs. 28 ± 15, $P = 0.002$), mean difference (95% CI): 8 (3–13); severe and non-severe cases were 33% (19/57) and 18% (10/56) among children aged less 1 year, respectively ($P = 0.06$, OR [95% CI]: 2.3 [1–5.5]). The frequency of the severity criteria items was: chest indrawing (31%), somnolence (21%), nasal flaring (6%), seizure (3%), inability to drink (1%), cyanosis (1%). No one presented grunting. According to BTS criteria,[11] severe CAP occurred in 96 (85%) patients and the frequency of the additional items was: RR >70 breaths/min for infants (21%), RR >50 breaths/min for older children (34%), difficulty in breathing (67%), dehydration (6%), axillary temperature $>39^{\circ}C$ (13%).

Overall, radiographic finding was right-sided in 77 (68%) cases and the upper lobe was compromised in 36 (32%) cases; both lobes, upper and lower, were compromised in 5 (4%) patients. The frequency of radiographic alterations was: alveolar (97%), interstitial (4%) and alveolar-interstitial (2%) infiltrate, consolidation (80%), pleural effusion (14%), atelectasis (10%), hyperinflation (4%), abscess and peribronchial thickening (1%, each). Pneumatocele and pneumothorax were not found.

The assessment of radiographic findings according to severity (WHO criteria) is shown in Table 1. By analyzing data stratified to age, the frequency of upper lobe involvement was significantly higher among severe cases only for those patients aged ≥ 1 year (13/35 [37%] vs. 7/45 [16%], $P = 0.03$, OR [95% CI] 3.2 [1.1–9.2]). The specificity and positive predictive value of upper lobe involvement for severity among the latter group of patients were 84% (95% CI 70–93%) and 65% (95% CI 41–84%), respectively. Children with upper lobe involvement were younger (months) than children with lower lobe involvement (20 ± 14 vs. 26 ± 15, $P = 0.04$), mean difference (95% CI): 6 (0.2–12). The analysis of age distribution in regard to each other radiographic finding and the

TABLE 1— Assessment of Radiographic Alteration and Severity of Community-Acquired Pneumonia (CAP) Cases According to WHO Guidelines[8]

	Severe CAP		Statistical analysis	
Characteristic	Yes = 57	No = 56	*P*	OR (95% CI)
Alveolar infiltrate[a]	57 (100)	53 (95)	0.1	—
Interstitial infiltrate[a]	2 (4)	3 (5)	0.7	0.6 (0.1–4.0)
Interstitial-alveolar infiltrate[a]	2 (4)	0	0.5	—
Consolidation[a]	49 (86)	41 (73)	0.09	2.2 (0.9–5.8)
Pleural effusion[a]	8 (14)	8 (14)	1	1 (0.3–2.8)
Atelectasis[a]	4 (7)	7 (12)	0.3	0.5 (0.1–1.9)
Hyperinflation[a]	2 (4)	2 (4)	1	1 (0.1–7.2)
Peribronchial thickening[a]	0	1 (2)	0.5	—
Abscess[a]	0	1 (2)	0.5	—
Right sided alteration[a]	43 (75)	34 (61)	0.09	2.0 (0.9–4.4)
Left sided alteration[a]	14 (25)	22 (39)	0.09	2.0 (0.9–4.4)
Upper lobe affected[a,b]	23/53 (43)	13/55 (24)	0.03	2.5 (1.08–5.6)
Lower lobe affected[a,b]	30/53 (57)	42/55 (76)	0.03	2.5 (1.08–5.6)

[a]Results are reported in n (%).
[b]Five cases showed alterations in the upper and lower lobes concomitantly and they were excluded from this analysis.

assessment of radiographic findings according to BTS severity criteria[11] showed no association (data not shown).

DISCUSSION

Based on the foregoing data, chest radiograph alterations localized in the upper lobe were associated with severity among toddlers and older children under 5 years of age with CAP. Among those patients, involvement of the upper lobe predicts severity in 65% (95% CI 41–84%). It is important to emphasize that the evaluation of severity used in this study was based on two different well established criteria[9,11] which include signs and symptoms that must be evaluated on the admission of the patients. The BTS criterion is broader than the WHO one and the absence of association with the BTS criterion is attributable to its broader range. On the other hand, the WHO criterion includes signs and symptoms present on admission that predict death.[12] Children classified as severe CAP cases according to WHO criterion should be hospitalized and should be given antibiotics parenterally in order to reduce the risk of death.[9] Therefore, the association found between involvement of the upper lobe and severity according to WHO criterion is useful to reinforce the necessity for hospitalization and parenteral treatment among children aged as of 1 year with CAP and affected upper lobe.

This finding suggests a difference in the pathogenesis of upper versus lower lobe CAP regarding pulmonary ventilation. The pulmonary upper and mid lobes work in every breath and they are responsible for the tidal respiratory volume; on the other hand, the lower lobes work when the child signs, being responsible for the inspiratory reserve volume.[13] Therefore, the upper lobe is more used in pulmonary ventilation and the involvement of the inflamed parenchyma of upper segments represents an important impair in pulmonary function and respiratory distress. This might be the explanation for the association found in this investigation. The association found was restricted to children over one year of age possibly because the respiratory reserve is smaller among those aged under 1 year. The absence of association between severity and the type of infiltrate (Table 1) might have been influenced by the overall much greater frequency of alveolar infiltrate and the very rare frequency of interstitial infiltrate.

To the best of our knowledge, this is the third investigation in which radiographic findings are assessed as predictors of severity in childhood CAP. In a previous study,[5] the authors concluded that the size of consolidation and the side of its location could be used as predictors of severity of CAP among children aged more than 12 months, and left-sided CAP run a more severe course due to increased risk for pleural effusion. It is important to point out that those authors used data on the evolution of the patients to classify severity. Therefore, as we used findings on the admission of the patients to classify the cases, their results are not comparable to ours. We did not measure the size of consolidation proportionally to the thoracic cavity size and this is a limitation in our study. In another study,[14] children aged 0–15 years were included and perihilar changes were associated with severity according to the BTS criteria.[11] They differently categorized the radiographic changes into three broad groups (lobar, patchy consolidation or perihilar infiltrates); then, those results are not comparable to ours. Our results point to the necessity of hospitalizing children with CAP aged from 1 year onward with upper lobe involvement. The

prognostic value of the chest radiograph justifies ordering it during the evaluation of children with possible CAP.

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REFERENCES

1. Mulholland K. Perspectives on the burden of pneumonia in children. Vaccine 2007;25:2394–2397.
2. Scott JA, Brooks WA, Peiris JS, Holtzman D, Mulholland K. Pneumonia research to reduce childhood mortality in the developing world. J Clin Invest 2008;118:1291–1300.
3. Jadavji T, Law B, Lebel MH, Kennedy WA, Gold R, Wang E. A practical guide for the diagnosis and treatment of pediatric pneumonia. Can Med Assoc J 1997;156:S703–S711.
4. Donnelly LF. Maximizing the usefulness of imaging in children with community-acquired pneumonia. Am J Roentgenol 1999; 172:505–512.
5. Kumar P, McKean MC. Evidence based paediatrics: review of BTS guidelines for the management of community acquired pneumonia in children. J Infect 2004;48:134–138.
6. Grafakou O, Moustaki M, Tsolia M, Kavazarakis E, Mathioudakis J, Fretzayas A, Nicolaidou P, Karpathios T. Can chest X-ray predict pneumonia severity? Pediatr Pulmonol 2004;38:465–469.
7. Cherian T, Mulholland EK, Carlin JB, Ostensen H, Amin R, Campo M, Greenberg D, Lagos R, Lucero M, Madhi SA, O'Brien KL, Obaro S, Steinhoff MC, the WHO Radiology Working Group. Standardized interpretation of paediatric chest radiographs for the diagnosis of pneumonia in epidemiological studies. Bull WHO 2005;83:353–359.
8. El-Radhi AS, Barry W. Thermometry in paediatric practice. Arch Dis Child 2006;91:351–356.
9. WHO, World Health Organization. ARI in children: case management in small hospitals in developing countries. A manual for doctors and other senior health workers. Programme for the Control of ARI; Geneva: 1990.
10. World Health Organization., Global database on child growth and malnutrition: the Z-score or standard deviation system (WHO/NUT/97.4). Geneva: WHO, 1997 [online]. Available at: http: www.who.int/nutgrowthdb. Accessed on October 5th 2006.
11. British Thoracic Society of Standards of Care Committee. BTS guideline for the management of community acquired pneumonia in children. Thorax 2002;57:i1–i24.
12. Shann F, Barker J, Poore P. Clinical signs that predict death in children with severe pneumonia. Pediatr Infect Dis J 1989;8:852–855.
13. Guyton AC, Hall JE. editors. Respiration. In: Textbook of Medical Physiology. 11th edition. Philadelphia: WB Saunders Company; 2005. pp 476–490.
14. Clark JE, Hammal D, Spencer D, Hampton F. Children with pneumonia: how do they present and how are they managed? Arch Dis Child 2007;92:394–398.